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The Institute of British Foundrymen
The Institute of Vitreous Enamellers
The National Ironfounding Employers' Federation
The Welsh Engineers' and Founders' Association
and
The Foundry Trades' Equipment and Supplies Association

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Welding and the Foundry

The use of fabricated welded steel for parts previously made in the form of castings came from the United States, and if the acceptance of this new form of construction as a general thing prior to exhaustive tests was less wholehearted in this country than in the States we had a right to point to our reserves of skilled foundry labour and our traditionally more cautious approach to sweeping changes. We are therefore particularly interested in signs that in the States the pendulum is swinging back and that an ascendancy period for castings has been entered on. It is suggested, in fact, that the better materials, equipment and technical knowledge of the foundry trade fit it to take a larger place in metal construction than at any time since the war. Welding to-day is accepted as a foundry tool, and the break-away from tradition that welding represented has encouraged the founder to approach the designer with suggestions for improving castings and even to make in cast form designs which had for many years been made in structural steel. In other cases jobs in the States are a combination of rolled steel sections and castings; while in still other cases foundries divide large and complicated pieces into several parts, cast them separately and weld them together. In this connection an investigation was carried out by a Westinghouse engineer on cast and rolled steel with the following broad conclusions. The cast steel he used can be successfully welded by the electric arc either to cast steel or hot rolled low carbon constructional steel by bare or fluxed electrodes. Also he found that welds on cast surfaces were not harmful, and that results obtained are approximately the same as those obtained from welds on machined surfaces. The strengths obtainable from various combinations of cast and rolled steel welded together appear to be much the same as those obtained from joints made in the usual way of all rolled steel. There is in this American experience ground for experiment in welding on the part of steel foundries. While it is of more immediate interest to steel foundries, the line of approach indicated also applies in a lesser degree to grey iron.

S.O.S.

Our lengthy sojourns abroad left on our minds one ineradicable impression, and that was that the foreign departmental manager in the metallurgical industries was inadequately seconded in his endeavours by his assistants, compared with his British confrère. That was a little more than a decade ago. Now we are making constant contact with innumerable executive officers and we find that Britain is to-day suffering from a similar complaint. Wherever we go we encounter the same story of the departmental manager being overworked. During the depression, now happily passed, it was found expedient to reduce staffs to skeleton proportions, and although trade is distinctly better, some firms are still pursuing the same policy, with the result that many responsible individuals are occupied doing essential yet trivial routine work which leaves no time for development activities. When they go on a well-earned vacation, they have to be worried with a heavy morning mail, to return on odd occasions for consultation, and, in general, to convert their holiday into a part-time affair. This is a definitely unsatisfactory state of affairs and to the general detriment of industry. There must be in a great industrial country such as Great Britain an ample reserve of young men well qualified to assist and, if necessary, to take charge of a department of an industrial establishment—at least temporarily. We are already aware that this condition of constant overwork is rendering responsible officials somewhat behindhand in a knowledge of the more recent developments. The plea of insufficient time to study, to travel, to meet with their colleagues in industry is only too often justified by an examination of their too-onerous duties. We attach the greatest importance to freeing responsible officers in industrial organisations from the worries of routine work in order that they may devote at least some portion of their time to surveying the department under their charge in the light of modern progressive ideas. Every manager should have the opportunity of viewing his department from the angle of an independent outside observer, and not eternally through the restricted orifice afforded by his own office window.

XUM

Facing the Fall

(BY A METAL BROKER.)

To say that the setback in the quotations of copper and spelter have upset the non-ferrous trade would be an under-statement, best corrected by an excursion into superlatives in an expression of the conviction that to many it has proved to be a sledge-hammer blow. Obviously, at these low prices business in residues and low-grade scrap becomes very difficult, and copper-bearing material, which in the earlier months of the year could be turned over at a bare profit, will be consigned to the dump, unless held on the offchance of a rise in the value of virgin metal. To anyone who fancies a long-term investment it is undoubtedly the right time to buy, and prudent bear operators should make sure of their profits, but the position presents many difficulties to the bull speculator who is looking for a quick return on his venture.

To those thunderstruck individuals who remark rather naively: "Surely prices cannot go any lower!" there can only be one reply and that: "They certainly may!" for the fact that standard copper has broken £30 and that spelter has gone below £14 is no guarantee whatever that the decline has spent itself. Actually, the pointers still indicate a further drop, and before this article is published the fall may have come, but it is, of course, reasonable to expect that at existing levels the decline will not be nearly so rapid as in the initial stages of the slump, for obviously more encouragement is given to buyers to back their fancy. An entirely new set of circumstances has been created with Germany practically out of the running as a buyer, while the threat of large-scale labour troubles in the States is a warning which cannot be disregarded. "This Changing World" is something of a catch-phrase to-day, and it is perhaps unwise to take too much for granted; it is certainly unwise to prophesy price levels when circumstances never encountered before are developing day by day.

Hope is one of the greatest assets given to humanity, and just because we are all buoyed up by the expectation of better times ahead a setback comes hard and only too often catches us napping. Bulls by instinct, we find it very hard to lay our plans for a fall, and it requires courage, experience and a well-disciplined mind to operate on the bear tack. Apart from professional dealers on 'Change, most people are compelled by force of circumstances to budget on a rise in values, for the manufacturer, the merchant and the producer all have stocks they wish to keep turning over, and, broadly speaking, most potential buyers only come in with both hands when the market looks good. In the writer's experience most people allow their estimate to be coloured by what they want to happen, and in consequence they fail to discern the weak points in the situation.

To sell standard copper below £30 seems wrong, and from an investment point of view no doubt it is, but for anyone who wants to protect a long position in the absence of demand by customers it is undoubtedly the right thing to do, for do not let us forget that bull points are very difficult to find to-day, and it looks as if there will be plenty of copper to satisfy the autumn revival of interest—when it comes. There seems to be some prejudice in the minds of many people against hedging commitments by making what is popularly known as a short sale, and traders who would not hesitate to cover sales by buying standard hesitate to insure against *lack* of sales by selling warrant copper forward. At the back of their minds one imagines that there lurks a fear of being squeezed, but no one except the broker who executes the selling order knows of the operation, and after all how long is it since we saw a corner in copper? Latterly the weekly turnover on the metal exchange in copper has been running at about 10,000 tons. You wish to hedge 250 or 500 tons? Spread over the five days it will hardly be noticed.

It is very difficult for manufacturers and merchants in the non-ferrous trades to avoid keeping a certain amount of length in the ordinary way of trade, for they must ensure cover not only for orders, but also against works' requirements and the manufacturing programme. This means that there is inevitably a fluctuating tonnage of copper at risk, and just because of this we find that sentiment looks more for a rise than a fall in values. There are times, and the earlier months of this year serve as an example, when it is reasonable and right that unsold copper should be held for a rise, but when the business sky becomes rapidly overcast and customers withhold their orders, then is the time to shift your ground and seek protection by selling forward on the Metal Exchange.

Who's Who in Vitreous Enamelling

No. 3.—MISS E. CHRISTINE ELLIOT

Miss E. Christine Elliot, the popular honorary secretary of the Institute of Vitreous Enamellers, is a London girl, who, though of tender years, is highly experienced as a business executive. She speaks French fluently and also has a fair knowledge of German, as she has held responsible positions in both France and Germany. Amongst business activities with which she has been associated are electrical engineering, radio, lamps, X-rays, automobile engineering, shipping, insurance, oil companies, films, and legal work. For the last three years Miss Elliot has been attached to the Sterling Company as Mr. B. B. Kent's private secretary and general assistant. This period has seen the initiation and development of the vitreous enamelling process at the Sterling factory.

MISS E. CHRISTINE ELLIOT.

MESSRS. SCOTT'S SHIPBUILDING & ENGINEERING COMPANY, LIMITED, have launched from their Cartsburn Dockyard the single-screw passenger and cargo motorship "Yunnan," built to the order of the China Navigation Company, London. The machinery is a five-cylinder single-acting heavy-oil engine of Messrs. Scott's special design, and works on the two-stroke cycle with airless injection. All the auxiliary machinery is electrically driven.

Random Shots

Some of the foundry boys (and girls) are visiting Hamburg this week-end. There is no particular reason why they should, but they just thought they would. The small daughter of a Yorkshire foundryman is accompanying the party and naturally asked whether the "Monte Pascoal" was a champion-ship. Were there any "cellars" in the ship and did the "bow(e)s" bump? "Marksman's" answer to this is In Verity, no, and the ship is of steel not Wood, and that it belongs to the Hamburg-America, not the Leyland Line, and that for the life of him he can't bring in the names of Sutcliffe and Macaulay.

* * *

"Marksman" wonders how many foundrymen know that an ancestor of Mr. Sellars, the captain of Yorkshire, invented the first moulding machine—the Darling & Sellars. Mr. Sellars' father also played for Yorkshire. There are several other prominent foundrymen engaged in cricket, such as Mr. G. R. Jackson, of Clay Cross, who plays for Derbyshire. Then, of course, before the war Mr. T. L. Taylor, of Taylor Bros., of Leeds, was prominent in Yorkshire cricket.

* * *

At football, no doubt, many foundrymen have achieved notoriety. Mr. J. Roxburgh played for Sheffield United, and Mr. Frank Cree was with Notts County. Mr. Percy Fox-Allin, a colleague, was an Irish Rugger International. Amongst foundrymen who have attained eminence in the sphere of politics are Mr. Arthur Henderson, whose signature adorns "Marksman's" passport, Mr. Hoover, and Mr. G. Washington, whilst Mr. Baldwin and the Chamberlains are not very far removed from the craft. Outstanding in art are Benvenuto Cellini and Leonardo da Vinci. The former—a sculptor and goldsmith was a brilliant bronze founder, whilst the latter is credited with the invention of the air blast as a factor in the operation of metallurgical furnaces.

* * *

Now that women are entering into the inner circles of foundry activities, as witness the appointment of Miss Elliot as honorary secretary of the Institute of Vitreous Enamellers, "Marksman" would point out this is not the first occasion that foundrymen have employed the fair sex in such a capacity. The first was Miss Margery Pittuck, who at one time acted as secretary and later as chairman of a junior section organised in connection with the London Branch of the Institute of British Foundrymen.

* * *

A bolt is a thing like a stick, of hard metal, such as iron, with a square bunch on one end, and a lot of scratching wound round the other end. A nut is similar to a bolt, only just the opposite, being a hole in a small chunk of iron sawed off short, and wrinkles round the inside of the hole.—"600 Magazine." MARKSMAN.

Correspondence

[We accept no responsibility for the statements made or the opinions expressed by our correspondents.]

Mechanisation

To the Editor of THE FOUNDRY TRADE JOURNAL.

SIR,—Your remarks on mechanisation in the JOURNAL of July 26 appear to be very apt and sound. There are undoubtedly a lot of snags to be met with in the consideration and application of any mechanical scheme, but they should not deter the analysis of existing conditions and a reasonable application of mechanical means.—Yours, etc.,

G. W. BROWN.

162, Wheeler's Lane,
King's Heath,
Birmingham, 14.
July 31, 1934.

The Mechanical Production of Cores*

By W. J. Molineux

Progress in Core Production

Until comparatively recent times very little had been attempted to cheapen the production of cores by the use of machines. All are familiar with the well-known "sausage"-type machine for making round cores in lengths, and also with the various mechanical contrivances for assisting the core-maker by turning over the corebox, stripping the core, etc. In some instances, too, cores are made by jar ramming or squeezing, but these methods of production are limited in their application to cores of the simplest kind, and the time saved over hand production is relatively small.

This is a matter of some surprise when one realises the failure on the part of engineers to

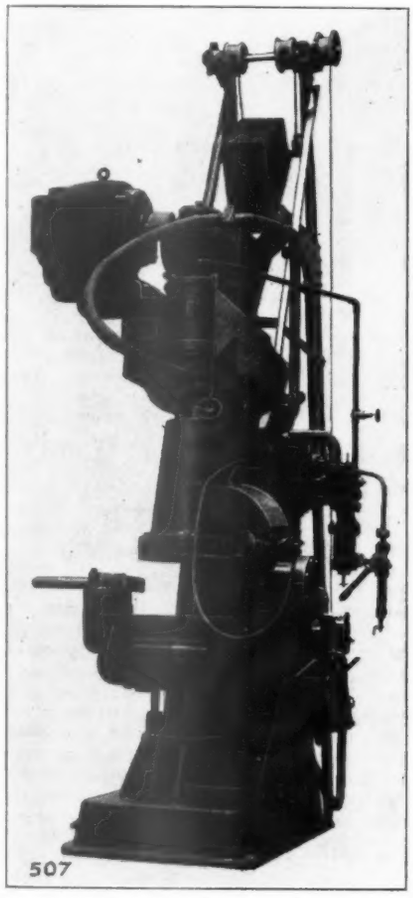

Fig. 1.—The August's Borrmann Core-blowing Machine.

exploit this branch of the industry. It is even more surprising since most of the old core-making difficulties and uncertainties disappeared with the advent and development of oil sands, as to-day it can be stated without qualification that cores of known strength and permeability, and which will give off known quantities of gas, can be produced with unfailing regularity. One's surprise turns to sheer amazement when comparing this state of stagnation with the developments that have taken place in other branches of engineering.

Most founders have seen praiseworthy developments, for instance, in machine tools, equipment and technique. Cutting speeds have increased enormously. Cast iron is now being cut at 700 ft. per minute. A few years ago this speed would have been thought impossible. In 1914 the U.S.A. Navy Department specified that a $\frac{3}{8}$-in. lathe tool should stand up for 20 min. with a $\frac{3}{16}$-in. cut and $\frac{1}{16}$-in. feed at 60 ft. per min. without regrinding, cutting annealed medium-carbon steel. These modern speeds have been made possible by improved cutting materials, and have necessitated revolutionary changes in machine-tool design; and the machine-tool maker has risen to the occasion and met the requirements in a comparatively short time. In fact, in many branches of engineering one would soon be out of business by the practice of ten years ago. The improvements in measuring instruments, both in the attainment of greater accuracy and speed, are outstanding. The progress made by direct competitors, the welding engineers and plastic moulders, is noteworthy, as their business was negligible ten years ago. Few founders drive a car that is ten years of age; yet they use methods in their core-shops many times that age, with complete complacency. Why is this? Is it because the equipment engineer has been lacking in ideas? Is it because the founder has been unenterprising, or is it through failure on the part of those in control to provide the necessary money for development purposes? Yet it is generally agreed to-day that money wisely invested in foundry mechanisation—and the core-shop is no exception—can show a substantial return. It cannot be that the core-shop practice reached finality years ago. Whatever the true reason, the fact remains; and even to-day one finds it difficult at times to persuade founders to abandon their obsolete methods. In the more modern foundries considerable progress has, however, been made in other departments, and moulding machines of reasonable efficiency are in daily use. The advantages of mechanisation, embracing efficient moulding-machine practice and controlled sand preparation, are now being appreciated and exploited by intelligent founders.

Not many years ago machine moulding was looked upon with almost as much suspicion as the mechanical production of cores is to-day. For instance, during the war, and immediately after, very few castings such as cylinder blocks and crankcases were machine moulded. A very different state of affairs exists to-day, and it is suggested that in a few years' time few foundries will be without their core-making machines, as circumstances will compel the adoption of these methods.

Existing Mechanical Aids

Most founders are familiar with the rotary core machine, first marketed, it is thought, by Wadsworth in America. This machine has proved very useful, but it had very definite shortcomings. Considerable improvements have, however, been made recently in this type of machine, and to-day straight cores of almost any section can be made true to 0.001 in. Other machines used in core-making such as jar rammers, squeezers, etc., are so familiar and so closely follow moulding-machine practice that they need no special comment.

Core-Blowing Machines

The most promising machine to-day is the core-blowing machine. In this machine the sand is projected by compressed air—usually at 80 to 100 lbs. per sq. in.—into the corebox at such velocity that the box is completely filled in a second or so. It follows, therefore, that when the conditions are standardised for any particular box, cores of uniform shape, size and quality are consistently produced.

Strange to say, all the core-blowing machines originated abroad, either in Germany or U.S.A.; but one machine at least is now being produced in this country. It is probable that the first commercially successful machine was the one produced by Demmler Brothers. A similar type of machine is made to-day by the Osborn Machine Company, Cleveland, Ohio, U.S.A. Another machine in which the blowing principle is akin is the one made by Zimmermann in Germany. A further German machine employs a somewhat different principle in blowing. In this machine—the Albertus-Revolver—sand is put into a hopper in the form of a large hollow disc on edge. When blowing a core a hollow cylinder cuts a wad of sand out of the container and the necessary quantity of this is projected into the corebox horizontally.

A machine which was patented in Germany by Borrmann is now made in this country, and has made considerable headway. It has as its central feature a stirring device for aeration of the sand. This enables the stiffest sands to be blown with complete success. Cores from the smallest up to about 80 lbs. in weight, can be successfully made on this machine. These larger

Fig. 2.—The August's Borrmann Core-blowing Machine with Bucket Loader.

cores, of course, call for machines of robust construction and many important special features in design. For instance, when "blowing" a core using an open-top corebox of large area, such as a motor-car crankcase or gearbox, considerable pressure is exerted at the instant of filling between the top of the corebox and the blowing plate of the machine. This has to be taken care of by an opposing and greater pressure from below, so that the joint between the corebox and the blowing plate is maintained.

Technique of Core-Blowing

There is, so far, comparatively little exact knowledge of the fundamental principles of core-blowing; most of the success so far has been attained by empirical methods. There are, however, certain simple points that stand out clearly, and which must be studied if success is to be obtained. These are: (1) The most suitable and adequate means of conducting the resident air from the corebox. Upon the efficiency of this depends to a great extent the success of core-blowing; (2) a proper understanding of the path taken by the sand in building up the core;

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* A Paper read before the Birmingham, Coventry and West Midlands Branch of the Institute of British Foundrymen.

(3) the most suitable point of entry for the sand, and (4) the best type of sand for the particular work in hand.

With reference to (1)—air release—this is made easy on the Borrmann machine for most coreboxes by the provision of a device known as "an air-release plate." In other cases the air is released by fixing gauges at suitable places in the coreboxes themselves.

Point (2) is intimately connected with (1), and it is often found advisable to encourage the flow of sand in a certain direction by providing air release at a point so that the ingoing sand will follow it to its exit.

With reference to (3), care should be taken when fixing the blowing place to guard against the sand striking and passing across a projecting part of the corebox, such as a lug or boss, as, if this takes place, the part may be damaged.

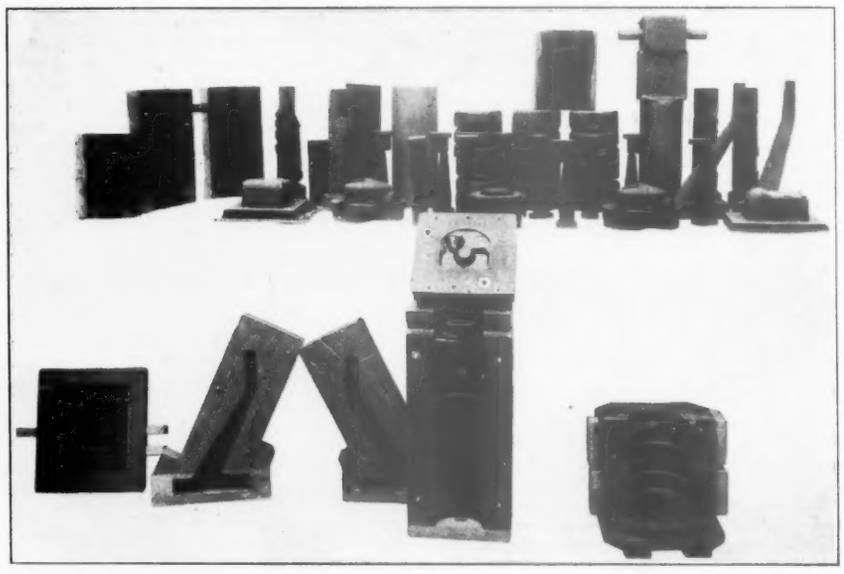

FIG. 3.—GROUP OF OIL-SAND CORES AND COREBOXES ILLUSTRATING THE TYPE OF WORK DONE ON THE MACHINES SHOWN IN FIGS. 1 AND 2. THE TALLEST CORE IS 2 FT. HIGH AND WEIGHS ABOUT 40 LBS.

Generally speaking, the sand should take the shortest possible route to its final place in the corebox.

Point (4) refers to sands. This is a common-sense matter, and in making a decision the requirements of the casting and the altered conditions due to "blowing" must be taken into account. For instance, where it is desirable to dispense with wires in a core, a sand having the maximum transverse strength is generally necessary.

Difficulties and Advantages of Core-Blowing

It soon becomes obvious, when first tackling core-blowing, that those cores most easily produced by hand are sometimes the most difficult ones to blow, and *vice versa*. Take as an example a shallow flat core of large area, which would be a simple core to make by hand. This would probably be somewhat difficult to produce by blowing, unless blown on end or its edge. On the other hand, a long round core with chambers and projections, which would be made by ramming up each half of the corebox and then "jointing" in the "green" state, and the necessary rod or wire reinforcement would be "bedded" in, would require some little skill, is a comparatively lengthy job, and trouble is usually encountered through the core-box not being completely closed when "jointing." Dried cores made in this way will often part at the "joint." This type of core can, however, be quickly and easily "blown" without any "jointing," and the rod inserted is firmly fixed in the core, as the sand is actually blown on to it. Further, there is no fear of over-size cores through the two halves of the box not being closed, as the corebox is clamped in the machine during "blowing." The same applies to exhaust pipes, inlet manifolds, and similar cores where "jointing" would normally be resorted to when making by hand. It is difficult, and sometimes impossible, in blowing cores to insert vents in some extreme cases, although this difficulty is often offset by using a core-binder which will give off the minimum amount of gas when the casting is poured.

Another advantage of "blowing" over hand-making is often found from the fact that usually only one comparatively small hole is required to admit the sand to the corebox. This makes it possible to have all the other openings closed, thus avoiding "strickled" faces with their inaccuracies. There is the further time-saving advantage that certain cores can be "blown" with the open face of the corebox in contact with the drying place, and when the box is stripped from the core, no turning over is necessary. A great saving in time is often effected by this means on high-production jobs.

A further advantage that cannot be overlooked is that in producing those cores that can be made by "blowing" one is practically independent of "skilled" labour, since youths and girls can operate these machines without any previous training. This, of course, calls for someone to be in charge of rather higher skill than is normally met with in this department. Someone preferably with a mechanical turn of mind and organising ability.

It will be readily appreciated that as the time actually taken in the "blowing" of a core is relatively small—5 sec. at the outside for the largest core—organisation plays an all-important part in the success of the enterprise. For instance, in the time study of a certain core which takes 8 min. to make by hand, it is found that 6 min. are taken in ramming the core, and 2 min. in stripping the core, reassembling the box, etc. When put on to the core machine it is found that the 2 min. remain, but the 6 min. come down to 4 sec. It therefore becomes necessary to have a relay of coreboxes, with one operator "blowing" and several assistants stripping and preparing coreboxes, if the greatest advantage is to be obtained from the use of the machine.

Another valuable aid to production is secured by "blowing" several cores simultaneously in a multiple corebox. Practically the same time is taken to "blow," say, eight or ten cores in a multiple box as would be taken to "blow" one core in a single corebox. Certain well-known branches of the foundry industry use cores which are peculiarly adapted to this method of production, with resulting great economies.

Conclusions

So far as can be definitely stated at present the advantages of core-blowing can be summarised as follow:—(1) Much faster production of cores and a great saving in labour; (2) the production of more uniform cores, in size, shape and quality; (3) a considerably greater output per box, thus avoiding duplication of coreboxes; (4) skilled coremakers are generally unnecessary in the actual making of the cores, and (5) from the few tests taken it appears that the resultant cores have considerably better physical properties, such as transverse strength, permeability value, etc.

So far, the most complicated cores used in cylinders cannot be produced by "blowing," although machines are working daily on jacket cores for side-valve cylinder heads. Other cores that are being made in large quantities are those for gearboxes, differential cases, cocks and valves, inlet and exhaust manifolds, crankcases, soil and rain-water specials, plumbers' fittings, etc.

It will be appreciated that although the author is able to show a few examples of "blown" cores, many others, often of greater intricacy, are being produced daily. Enough has been said, however, to arouse interest.

In conclusion, the author would like to express his thanks to those who have assisted him by loaning lantern slides, supplying cores, etc. They include Messrs. J. W. Jackman & Company, Limited (lantern slide); International Combustion, Limited (sample cores); British Piston Ring Company (for permission to show slides); The Fordath Engineering Company (for lantern slides and the supply of sand); Messrs. August's, Limited (lantern slides), and The Sunbeam Motor Car Company.

Notes from the Branches

The Council of the West Riding of Yorkshire Branch of the Institute of British Foundrymen, at its summer meeting, has embarked definitely on a campaign of developing to the utmost what it believes is plentiful latent talent among the Branch's own members, and in pursuance of this policy has issued a direct invitation to members to submit, before the opening of the winter session, if possible, short Papers on subjects connected with founding. The Papers will be examined by the Literary Sub-Committee and about three will be selected for presentation to general meetings during the session opening in October. The Branch-President (Mr. A. W. Walker) has offered to present a prize to the member whose Paper is judged by the sub-committee as the best.

Institute of Vitreous Enamellers

The first annual general meeting of the Institute will be held in Birmingham from Friday, September 28, to Sunday, September 30. On the Friday evening there will be a reception, and a banquet followed by dancing. On the Saturday morning a visit is to be made to a large stove works, and after luncheon members will hear an address from the President, Dr. J. W. Mellor, F.R.S., and a Paper of a general character by Mr. A. England. This will be followed by a discussion. It is proposed to organise a theatre party in the evening, and on the Sunday a motor rally to Stratford-on-Avon, members to provide transport by private cars.

Test-Bars from the Foundryman's Point of View*

By S. Southcott

If any problem has been discussed so fully or has had so much written about it, the author considers the problem of test-bars takes priority over all others. Committees have sat and revealed various methods for their uses; Papers have been read before almost every Branch of the Institute of British Foundrymen and all other institutes associated with engineering; yet it is not thought there is any subject which affords such little value to the foundry layman. After weeks of research on the subject, the author is still groping for knowledge of matter of real value which he could bring into use for the benefit of the foundry. The testing of castings presents varied and difficult questions to each branch of engineering, more especially the foundry. On almost every job for which the founder has to cater to-day, specifications embodying the requirements of the purchaser usually contain clauses appertaining to such points as soundness and finish; mechanical and hydraulic tests have to be carried out before acceptance, and, in most cases, such tests are supervised by the purchaser's representative. Sometimes, of course, the manufacturer's good faith is taken for granted. It is not proposed to deal with all the tests called for by purchasers, as most of them can only be conducted in the laboratory, to which very few foundrymen have access. These embrace structure tests, which include several forms of test readings; the punch or ring stamp test, the shock test, and the density (porosity) and several others.

Tensile Test

This test has been the bone of contention between engineers all over the world. It is true to say that the engineer bases his design and factors of safety on the basis of strength of material, yet he avoids, as far as possible, tensile stresses in the cast parts of his machine. It must be admitted that the major portion of failures in castings are in tension, and one would think that, as far as the demands for correct tests are concerned, the greatest demand should be more on the nature of tensile than any other, and, knowing the brittle nature of cast iron (and this they now try to avoid by the introduction of nickel and other alloys), they agree that this test is less informative than some of the other tests, besides, this test is also condemned from the standpoint of expense; it is something which the average foundryman avoids as far as possible. Furthermore, it gives no indication of the actual yield point or of any vestige of ductility which might be held between a tough and a brittle bar; it gives only the *tensile strength*. Personal experience of it was in conjunction with a colleague, the works engineer, who carries out all tests of tensile strength, and it is interesting to note that he fully agrees on these points.

Compression Test

The compression test, which, to some extent, gives similar results, could, it is thought, draw out far better information than the tensile test, though not used to any great extent in this country at the present time. It could be assumed that the material is stressed uniformly and can acquire a better indication of the actual stress at which failure occurs.

Shear Test

Another test which receives more serious attention on the Continent than in Great Britain is the shear test. It was originally introduced by a French engineer and applied to test-bars cut out of the actual casting. It was considered (and still is in some quarters) to be far more advantageous to the engineer than any of the other tests; but the foundryman, whose time and worries demand his close attention in many directions can leave this method to the experts.

Impact Test

Again, there is the impact test, which calls for particularly close attention. It is not considered of much use by ironfounders in this country, but in France it occupies a very prominent position. It is looked upon as a clumsy method here; the results are rough and most unreliable, and it does not show a very close relation to the results of other known tests. Several methods have been adopted in different countries, but these are mostly used for steel, and are considered more appropriate to steel than cast iron.

Repeated Impact Test

Kulnel, in Germany, introduced the repeated impact test—a method which has induced the British Cast Iron Research Association to investigate its uses, and this body will, perhaps, issue a report in the near future on its findings. It is called the repeated impact test. In this test the bar is rotated after each successive blow.

Brinell Test

The Brinell test is another form of testing, and is universally adopted, and apparently lends itself admirably to steel and to the non-ferrous castings, and it is only in the latter direction that the author has had occasion to use it. This is an excellent method of ascertaining segregation in copper and other alloys, phosphor bronzes, etc. Some experiments on phosphor bronze were carried out for the purpose of lead segregation, which were most interesting, and proved what an excellent component nickel was as a preventive. Usually for this purpose an inch square bar, 15 in. long, was cast on end. Brinell tests were then applied on every inch of its length, and these give a very fair testimony of what happened. Dr. Swift, in The Foundry Trade Journal of March 24, 1932, describes it as follows:—"This test is different in character from all other tests, for the ball impression is not dependent to any appreciable extent on the crystalline graphitic conditions which control the mechanised strength, but upon the constitution of the crystals themselves."

Transverse Test

It is proposed to deal with the most simple method, and in my personal opinion the most reliable of all tests for general foundry practice, namely, the transverse test, which includes bending strength and deflection. Mr. J. G. Pearce, of the British Cast Iron Research Association, has given very good reasons for its superiority over the shear test, and Rudeloff, in his work before the Society of German Ironfounders, offers quite definite reasons for its use in preference to other forms of test.

If it can be agreed that the best method for general foundry practice is the transverse test, then several questions arise, namely:—Are test-bars to be cast separately; or are they to be cast on or with the casting specified, or made of pieces cut out of the castings? These two questions require very careful consideration, and open out an extremely wide field for discussion. Examining the latter part first—should they be made out of the actual castings? There is certainly much to be said in favour of this argument. Since the engineer naturally wishes to know the properties of the castings which he actually uses, it would, at first sight, appear rational that founders should test one or more of the castings supplied. There are, however, various difficulties to surmount in adopting this simple method. When castings are small and supplied in considerable numbers, the sacrifice of a few is quite feasible. On the other hand, for large castings usually supplied singly or in small numbers, such a procedure is then out of the question. Again, the shape and design of the castings frequently render them most unsuitable for transverse testing and, possibly, most unreliable. On one occasion the author broke up a waster casting of a heavy crab, which afforded an opportunity of cutting three inch-square bars suitable for a test, one from the outer edge, one halfway in and one from the centre of the cast. The result was as follows: The outside bar gave 3,264 lbs., the next 3,079 lbs., and the middle was quite weak, showing 2,610 lbs., revealing how impossible it is to rely on part of the casting for a test-bar.

Cast-on Bars

The second point is as to whether test-bars should be cast on, and this presents further difficulties. Several questions naturally arise: Are they to be cast on bottom or on top of the casting? Certainly, two different readings would be obtained from two bars cast in this way. It appears very simple to cast test-bars on the castings, but every founder is familiar with the fact that in the great majority of materials those parts of a casting which have a thin section, and cool more rapidly in these sections, are harder and stronger than parts having a thick section which undergo a more gradual modification. Furthermore, there is the risk of drawing through a badly-designed casting. One part may be quite sound, another porous; in fact, Brinell tests taken on different parts of castings, top and bottom and sides, show wide differences. From the technical point of view, these two methods are not only unreliable and unsound, but they certainly become too expensive for practical purposes. The only important point is that it brings forth one fact, and that is, that the engineer can be satisfied that his castings are composed of exactly the same material as his test-bars; it does, at any rate, afford him the satisfaction of knowing that they are cast from the same ladle of metal, but whether or not he has a fair conception of the material requirements is a question difficult to answer without further enlightenment, and it is preferable to leave it at that juncture for the consideration of the chemist and metallurgist.

Separately-Cast Bars

The next point is whether test-bars should be cast separately from the same ladle of iron. It was earlier stated that some engineers rely on the good faith of the maker in regard to the taking of tests. The method usually adopted by the author is to cast three test-bars in a box on a slope of about six inches. Such a method is most satisfactory and should give a fair reading. Naturally, owing to the rate of cooling, the middle bar will give a slightly better reading, but it will be nothing in comparison with other irregularities if different methods were adopted. For instance, a typical test would give 24, 23, and 25.3 cwts. breaking load associated with 0.15; 0.13, and 0.17 in. deflection, the last being the centre bar. Are transverse tests to be carried out with the top side of the bar in compression or in tension? This may seem an insignificant point to some people, but in two bars from the cast the figures given in Table I were disclosed. This method is most satisfactory, particularly in the case of cast iron, and it is necessary to consider in this connection the question of the quality of the test-bar corresponding with that of the casting which it is supposed to represent. It has been shown that the strength of castings is, to a certain extent, controlled by a variety of factors—composition, melting conditions, casting temperature, size and design of

* Extracted from a Paper read before the Wales and Monmouth Branch of the Institute of British Foundrymen.

casting, and even to the position and shape of feeding heads, runners and risers, the rate of cooling, the comparative freedom from such defects as cold shuts, slag-holes, sand grains, gas, spongy places, and so forth. The effects of these are more often mutually interdependent. Rates of cooling may, of course, be controlled in various ways, but all these complications render the production of a test-bar which affords an accurate indication of the quality of the casting by no means easy, and in cast iron the problem is rendered more difficult. If from a steel forging, a bar has a strength of, say, 25 tons per sq. in., it may be taken for granted that the same reading would be obtained (perhaps within a very narrow limit) in a test taken from any part of the forging; or again, say in a bag of bolts one could pick out any of them, put one through a certain test and, no doubt, safely say that the remainder would, if subjected to an identical test, give precisely the same results, but no such deduction could be drawn from a cast-iron casting, because different considerations arise.

Table I.

Condition of test.	Bar No.	Section of bar.	Breaking load in cwts.	Deflection in in.
Top surface in tension ..	1	1 in. × 1 in.	23.9	0.14
Top surface in compression	2	1 in. × 1 in.	27.0	0.16
Top surface in tension ..	3	1 in. × 1 in.	25.4	0.15
Top surface in compression	4	1 in. × 1 in.	28.1	0.165
Top surface in tension ..	5	2 in. × 1 in.	33.2	0.46
Top surface in compression	6	2 in. × 1 in.	37.4	0.54

Again, in a large casting, which cools more slowly than a small one, or a dry-sand casting, which, by being cast in a dry-sand mould, would contain graphite in larger size, the combined carbon is less and the strength correspondingly reduced. To prove this, the author cast from the same ladle of iron three bars 3 in. dia. and 14 in. long, and three bars $\frac{3}{4}$ in. dia., and tested with the $\frac{3}{4}$-in. bars in the rough: comparisons were useless: the rough $\frac{3}{4}$-in. bar showed far stronger than the 3-in. bar. There is a marked diminution of relative strength in thicker bars, owing to the metal becoming more open and spongy when in thick masses, and also due to there being a proportionately smaller amount of hard skin. Thus, a 3-in. sq. bar has relatively barely two-thirds the transverse strength of a 1-in. bar. The question then arises: Does the size of the bar related to the thickness of casting give a fair indication of the material strength of the casting? There is some concern as to the requirements of different grades which the Admiralty should adopt in regard to the different irons. It has been recommended that a certain scale of tests drawn up by a responsible body of experts suggests that the requirements of 13-ton iron should be a certain figure, and for a 15-ton iron a higher figure, whilst for the requirements of a 17-ton, further considerations were asked for. Now, what is really meant by the term "17-ton iron"? Would the maker be required to give a definite breaking load which would be comparable with the loads suggested on the lower-ton irons? The difference between the 13-ton and the 15-ton is a matter of 100 lbs. on the 0.875-in. bar, 12-in. centres, and a difference of 240 lbs. on a 1-in. by 2-in. bar at 18-in. centres, on 2-in. by 2-in. the difference of 1,000 lbs. There is on record a 2-in. by 1-in. bar, the breaking load of which was 3,088.8 lbs. on a 36-in. centre. If an equivalent could be made on an 18-in. centre, then anyone could suggest this as a sample iron for the purpose. There is also an iron with an average breaking load on three bars 1 in. by 1 in. of 3,500 lbs., and they just ask for 1,600 lbs. Something more definite should be given on these matters. According to one authority "It is not safe to stress ordinary cast iron in tension to more than 2 tons per sq. in. This just reveals one of the difficulties of the subject and how complicated it is for the layman to fit it in with the other parts of his work; it also shows how these complexities should always be envisaged in the manufacture of castings for which mechanical tests are required.

Acceptation Tests

British Standards Institution Specifications are, of course, very commonly employed to-day, and are continually being cited in the customers' demands. No. 321 of 1928 applies to grey-iron castings; it prescribes that the castings are to be made from metal melted in any furnace other than an iron-ore smelting furnace. One may be able to use this iron if the written permission of the buyer can be obtained; no requirements of composition are laid down, but a maximum percentage of phosphorus may be specified. There are the usual clauses relating to accurate moulding and lettering (if any), also as to freedom from defects. The buyer must state whether he wants tensile, transverse or other tests; he may specify that the bars shall be cast on, if, of course, the design and method of running permit, and there is also a clause that bars shall be made in the same manner as the castings (dry or green sand) and shall not be heat-treated after cast.

Dimensions of Test-Bars

These usually vary with the main cross-sectional thickness of the casting, and are divided for this purpose into three classes, namely, medium, small and large, the small including those not exceeding $\frac{3}{4}$ in., medium those between $\frac{3}{4}$ in. and 2 in., and the large over 2 in. in mean cross-section.

Table II.—*B.S.I. Test-Bar Dimensions.*

Test-bar.	Diameter.	Overall length.	Main cross-sectional thickness of casting represented.
S	0.875	15	Not exceeding $\frac{3}{4}$ in.
M	1.2	21	Over $\frac{3}{4}$ in. thick, and not exceeding 2 in.
L	2.2	21	Over 2 in.

A transverse test-bar cast to the dimension given in Table II and tested without machining must, when placed on knife edges set at a distance shown in column 2 (Table III), strain a load applied at centre of not less than that shown in column 3, and must show at breaking a deflection of not less than that shown in column 4.

Table III.—*B.S.I. Minimum Transverse.*

1	2	3		4	
Test-bar.	Distance between supports.	Minimum load.		Minimum deflection.	
		Grade A.	Grade C.	Grade A.	Grade C.
		Lbs.	Lbs.	In.	In.
S	12	1,185	960	0.12	0.10
M	18	1,950	1,600	0.15	0.12
L	18	10,000	8,950	0.12	0.10

The grades are set out in their different classes to suit special purposes, and have to give quite different results.

Another problem that faces the foundry layman is the relation of the test-bar to the casting supplied. The casting may have its different thickness, and if one attempts to cast bars of different thicknesses to compare with the castings one finds that different readings of different-size bars are to some extent misleading. A thick bar tested at a wider support gives a lower reading than a small bar tested with a narrow support. The variation will be readily observed with a 2-in. by 1-in. bar tested between supports of 36 in., and a 1-in. by 1-in. bar tested between 12-in. supports.

Again, it is often found that bars tested in the rough give better results than bars machined down to the same size. It is somewhat puzzling at times to discover the difference in these tests, casting bars from the same ladle giving erratic readings when carried out in these forms; sometimes the highest is the machined bar, and at other times *vice versa*. This is probably due to the fact that the skin of a green-sand bar contains minute superficial fissures which may cause premature rupture under test and, possibly, a release of skin stress, of which the fissures may be regarded as evidence. Bars cast in dry sand give more uniform readings; there again one misses that very harmful chill found in green-sand cast bars. The same can be said of oil-sand cast bars. Nor is one to assume that metal given a very high breaking load with a low deflection is the best metal for castings having to stand heavy service, such as cylinders, piston rings, etc. For example, a semi-steel is considered a good material for this work, yet it has been found in practical foundry tests that only a low breaking load is required to fracture it, but it will yield a high deflection.

The author always makes a point of taking test-bars of the first melt on a new truck of coke, and in attempting to control coke consumption in the cupola it will be found that there are differences between one truckload and another, and the constitution has a profound effect on the composition of the metal. Melting conditions, then, have to be kept as uniform as possible; the effect of temperature is so marked that one must resort to some form of bar to test these anomalies. The introduction of foreign matter into scrap gives trouble in the composition of the iron; pieces of brass, which are often unobserved in the scrap metal, give endless trouble. On one occasion the skin of the metal in the ladle gave indications of abnormality. Test-bars were taken from it and the metal was used for some balance weights which were ready at the time. One fracture revealed a white iron with a close grain, a second had a white tendency, whilst a third was grey with a close grain. After examination of similar scrap, it was found that a large proportion was covered with oil and grease and contained a quantity of yellow metal studs, hence this result.

Fluidity Tests

The other tests which are of great assistance to the layman are those which have no connection with the engineer and his work; some, such as a fluidity test, are invaluable in the proper control of metals in the foundry. It must readily be seen that the factors governing this test, and having most effect upon it, lie in the composition of the metal, in its temperature, and again in the temperature of the mould. Here we are governed by three different influences: that of the composition of the metal is obvious to everyone. Each constituent has some effect upon its conduct, but in a different manner and degree. For instance, a metal with a high sulphur content cannot be expected to show such fluidity as a metal with a high phosphorus content. Whilst sulphur has a detrimental influence, phosphorus has a good influence on fluidity. Again, temperature of the mould adds to this problem. The foundryman takes care in this matter, when making castings to a specification which calls for a metal of high sulphur content. Again, whilst a high temperature would naturally increase the fluidity of the metal, green sand, with its moisture content, tends very largely to lower the temperature, and consequently reduce the fluidity of the metal. Further, in cupola practice, everyone knows that in the early part of the melt the temperature of the metal is much lower than during a later period, and, therefore, in order to be sure that many of the castings are good, one must resort to some method of testing that can be carried

out very quickly, and this test is one that gives just what is required. Two bars are cast in a box on a small slope—the gate being the lower end—and an ordinary runner used. The bars used by the author are 12 in. long, 1 in. wide, $\frac{1}{8}$ in. thick, the gate end $\frac{1}{4}$ in. thick, one cast on edge and the other on the flat. If the metal flows through the pop-gates in the top end, one may be assured that the metal is suitable for running any thin work required. One may not have the metal suitable for, say, cylinders or piston rings, to come up to the top of the box, but if the bars are run to their ends, one then has a metal of such a temperature to turn out good-class castings, assuming the cleanliness of mould and the like.

Shrinkage Tests

The shrinkage test is another very valuable test to the foundryman, and affords him some idea of whether the metal is suitable for the castings required. Different methods are employed in various works. Some use the letter "K" as a pattern, which is in every way adequate. There are thick and thin parts which, when broken (and it is quite a suitable pattern for breaking), give a very fair indication of the conduct of the metal, provided that proper precautions are taken both in the temperature of the metal and its composition and kept as constant as possible. The author has never used the letter "K," but a series of toothed pieces, which induce similar results.

As a guide, it may be stated that irons having a long solidifying range, or those irons high in phosphorus and silicon, will apparently be the most solid before the bar is broken, but very likely considerable spongy places will be found inside; then, the irons having a short freezing range, or irons low in phosphorus and silicon, will show a sunken area on almost all the thick parts. In some of them may be found small draw-holes, with no spongy places showing anywhere.

In conclusion the author desires to thank his principals, Messrs. Taylor & Sons, for allowing him the use of their testing machines and time for carrying out these experiments of testing, and Mr. J. G. Pearce, the director of the British Cast Iron Research Association, for the use of the Association's publications.

Effect of Temperature on Metals and Fatigue

The session of the A.S.T.M. meeting, held at Atlantic City, from June 25 to 29, devoted to "Effect of Temperature and Fatigue of Metals," was featured by three extensive Papers in the high-temperature field and a description of a new high-speed fatigue-testing machine, with some tests of speed effect on endurance limit. The Report of the Joint Research Committee of A.S.M.E. and A.S.T.M. on "Effect of Temperature" was given, as well as the Report of the Research Committee on Fatigue of Metals.

The Paper on "The Interpretation of Creep Tests," by P. G. McVETTY, discussed the fundamental nature of the creep curve and the effect upon it of strain-hardening, annealing and other phenomena connected with long exposure of complex alloys to stress at elevated temperatures. Examples were given by Mr. McVetty to show how, under suitable conditions, creep data may be correlated. He mentioned that creep tests must be extrapolated if they are to have design value, and the time ratio may be as great as 100 to 1. Granting all the objections to extrapolation, it may be looked upon as a necessary evil.

In an interesting discussion of creep properties of 5 per cent. chromium and $\frac{1}{2}$ per cent. molybdenum-steel tubes, MESSRS. CROSS and JOHNSON, of Battelle Memorial Institute, pointed out factors of interest to producer and consumer alike, namely, the effect of carbon content, heat-treatment and variation of directional properties resulting from working during fabrication.

Increase in carbon content from 0.139 to 0.181 per cent. in a 4 to 6 per cent. chromium, 0.50 per cent. molybdenum steel increased the physical properties and creep resistance materially. Longitudinal material showed better creep resistance than transverse material of either carbon content, but the differences were less than 10 per cent. In comparing normalised and slow-cooled materials, the latter developed better creep properties.

Impact resistance of transverse material was lower than for longitudinal material. Impact tests made on specimens subjected to load and temperature for 1,000 hours or more, revealed no notable drop in toughness. With some of the structures resulting from initial heat-treatment, a slight reduction was noted, but a large measure of toughness remained.

H. M. WILTON and E. S. DIXON, of the Texas Company, discussed the ageing embrittlement of 4 to 6 per cent. chromium steel. This steel, with low carbon content, is being extensively used in oil refineries in the form of heater tubes, and it is at times subject to embrittlement after exposure to operating temperatures (approximately 900 deg. Fah.), and cooling when the plant is shut down. The authors conclude that normal failure of this steel in refinery use is accompanied by creep, with visible swelling, and that most heats show a high degree of susceptibility to temper brittleness. From a theoretical viewpoint, it is concluded that embrittlement is revealed by a drop in impact value, with, at most, only a negligible increase in hardness or tensile strength.

Catalogues Received

Foundry Equipment. Messrs. J. W. Jackman & Company, Limited, Vulcan Works, Blackfriars Road, Manchester, have just issued an abridged catalogue. It will be remembered that their full publication runs to some three hundred pages. This new brochure more particularly covers the machines and appliances currently in demand. It is built-up on the loose-leaf principle, so that fresh pages can be added from time to time. It is divided into six sections, readily referred to by a system of edge-cutting. First of all, melting appliances are dealt with, and herein we noted several innovations in cupola design, especially in connection with the tuyeres. The descriptive matter dealing with drum ladles well illustrates the need for loose-leaf catalogues, for we well remember about a decade ago noticing several of these in Jackman's showrooms, and, in answer to our inquiry as whether they were popular in Britain, Mr. Rawlinson stated that he could not give them away! To-day, in our visits to ironfoundries we have noted that they become exceedingly popular. We were particularly fascinated by the word "soif," used on page 16 in connection with the drum-type magnetic separator. None of our dictionaries has revealed the existence of this word, which, if pronounced in the French fashion, gives "swarf" and means, of course, "thirst!"

Sand-preparing plant is covered by Section 2, and includes the roller-barrel type, which ought to be capable of development to give an output of 40 tons per hour or more, for such a continous type of machine will be required in the future. The combined sifter and magnetic pulley appeals to us as being a type of machine that should find favour at the present time amongst the smaller foundries, as it will keep the floor sand clean.

Amongst new plant found in the moulding-machine section we noted that an electric vibrator is listed; in the past we have been caused some trouble to locate supplies of this commodity. In the core-shop section we encountered the first description that we have ever seen of the Osborn core-blowing machine, and look forward to seeing this machine at work. Sand- and shot-blast machinery is assuming increasing importance every year, and larger and more automatic plants are constantly being called for. It takes a complete page of the catalogue just to outline common applications. The range illustrated is very comprehensive, especially in respect to the barrel section.

The last section covers air compressors, receivers, oil and water separators. Altogether the catalogue is an exceptionally creditable production, showing an intelligent appreciation of the modern requirements of the foundry industry.

Electric Furnaces. We can well imagine that in the year A.D. 2134 or thereabouts some researcher into the early history of metallurgical developments will be ecstatic in his delight when he rediscovers the catalogue we have just received from the Electric Furnace Company, Limited, of 17, Victoria Street, London, S.W.1. In this well illustrated 28-page brochure there is a fascinating account of the early beginnings and growth of the electric furnace industry up to the present time. Naturally, being the publication of one commercial enterprise, the story is restricted to its own particular part—but anyone who is so thoroughly acquainted with this development as ourselves, must admit that the Electric Furnace Company were the real pioneers. It whetted our appetite for more, and we wish that someone with reasonable time at his disposal would write the early history of this fascinating development, giving due credit to that enthusiastic band which included engineers, metallurgists and operative melters. Though the brochure carries the reader through the various developments—Heroult single-phase, Heroult 3-phase, electrode manufacture, Ajax-Wyatt, to high-frequency melting—it serves as a thoroughly intelligent sales-promotion catalogue, as industrial progress combined with technical efficiency is thoroughly established long before the last page is reached. A comparison of the photograph on page 27, which shows the recently opened shop of S. Fox & Company, Limited, of Deepcar, with that of the original Heroult furnace installed in the works of Edgar Allen in 1910 shown on page 7, is an eloquent testimonial to the progress achieved. One extra line inserted on page 6 would have settled a controversy which was ventilated in our columns some months ago. This line would state whether the Edgar Allen furnace was engaged upon the manufacture of steel for castings or for tools and whether the distinction of first buying an electric furnace for purely foundry purposes should be accorded to Mr. Lake, of Lake & Elliott, of Braintree. Moreover, pretty much the same situation again arose over the installation of the motor-driven high-frequency furnace. We whole-heartedly commend a perusal of this interesting publication to our readers, to whom it will be sent on request.

Materials for Automobile Engineering Purposes. The Bureau of Information on Nickel has issued from Thames House, Millbank, London, S.W.1, two folders—the one (AA 2) dealing with automobile engines and the other (AA 3) covering automobile front axles, chassis and fittings. The arrangement is the same in both cases, that is, typical compositions are set out, together with the appropriate specification number, followed by a list of components with recommendations for sports and racing cars, light and heavy passenger vehicles and light and heavy commercial trucks. We deem these to be very useful publications and advise our readers, not only in motor-car foundries, but in other sections of industry to provide themselves with copies, as containing very many useful pointers.

XUM

The Elasticity, Deflection and Resilience of Cast Iron*

By J. G. Pearce, M.Sc., Director, British Cast Iron Research Association

Introduction

Several physical determinations on cast iron involve the measurement of extension or deflection under load—for example, the transverse strength and the modulus of elasticity. Cast irons do not yield a linear relation between the load and either the elongation or the deflection, and in the majority of cases the curvature towards the strain axis begins at the origin. For the purposes of the present discussion it is unnecessary to enter into the controversial issue as to whether truly elastic materials can exhibit

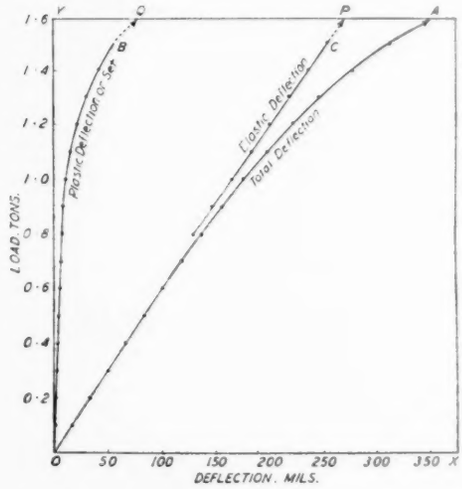

Fig. 1.—Load-Deflection Curves, High-Quality Iron.

a relationship other than linear, as is embodied in Hooke's Law, or whether departure even in the slightest degree from the straight line indicates plastic distortion or set. Some plastic distortion under load is characteristic of even the most elastic materials, and some return to the original condition of the most inelastic. Although cast iron is commonly regarded as a relatively brittle material, the range of irons now commercially made exhibits, in fact, a wide variety of properties between the extremes of brittleness (rigidity) and toughness (ductility) available, enabling a much wider range of service requirements to be met.

Deflection

The elongation of cast iron under tensile or compression under compressive stress are seldom taken, but the deflection is invariably recorded in the commonly-used transverse test. Specifications frequently embody, along with the breaking load, a minimum deflection, usually fixed empirically on a basis of experience or trial. It is generally considered that the breaking load gives an indication of the strength, and deflection of toughness. There is, however, among metallurgists and engineers, much uncertainty about the deflection figure. It differs little between bars of different shapes and sizes, and between irons of various qualities. Good irons and mediocre irons alike may have both high and low deflections. The effect of composition variations, alloy additions, heat-treatment, pre-stressing and other treatment is uncertain. The most obvious variation in deflection follows on changes in the transverse span—the distance between supports—which, of course, is invariably specified. The specification of transverse deflection, in fact, is not at present of any particular mechanical or metallurgical significance; it mainly ensures regularity and uniformity of product.

A few years ago the author adopted a method which yields more information than is usually derived from the transverse test as ordinarily conducted. It is very important to make the best use of this test, as it is virtually the only one which can be applied to any section that can be cast, and the strength alters appreciably with the section. The total deflection at fracture in cast iron is made up of two components, the elastic deflection, which disappears when the load is removed, and the plastic deflection, or permanent set, which remains after the removal of the load. In ordinary cast irons the deflection is predominantly elastic, being usually some 80 per cent. of the total deflection, and is comparable in magnitude with the deflection given by steels. The development in recent years of ferritic and austenitic cast irons, as well as the advance in the production of high-duty pearlitic irons, plain and alloyed, has brought about material modifications to the deflection figure, and has necessitated new criteria by which cast iron must be judged.

Table I.—*Chemical Analyses.*

Iron and Fig. No.	T.C. Per cent.	C.C. Per cent.	G.C. Per cent.	Si. Per cent.	Mn. Per cent.	S. Per cent.	P. Per cent.	Ni. Per cent.	Cr. Per cent.
1	2.70	1.01	1.69	1.97	0.98	0.13	0.16	0.95	—
2	2.59	0.02	2.57	5.85	0.91	0.10	0.05	—	—
3	3.21	—	—	1.75	0.63	0.11	0.99	—	—
4	1.89	—	—	5.68	0.94	—	—	18.01	1.43
6 & 9	3.50	—	—	0.84	0.36	0.07	0.15	0.98	—
7	1.57	0.78	0.79	0.33	0.09	0.16	0.08	—	—
8*A*	0.76	0.68	0.08	0.42	0.10	0.06	0.05	—	—
8*B*	0.88	0.66	0.22	0.62	0.10	0.06	0.05	—	—

In the results described in this Paper, unless otherwise specified, all transverse tests have been taken on skin-machined bars, which give figures less erratic, because less liable to notch effects, than unmachined bars. The deflection is given in mils (thousandths of an inch) on an 18-in. span (15 diameters on a standard 1.2-in. dia. bar), unless otherwise stated. All transverse and tensile tests are made in accordance with B.S.I. Specification 321/1928. Experience has shown that the material on either side of a transverse break can be used for further tests without risk, and that, on the same material, straight transverse tests give results concordant with those of tests involving the removal and restoration of a gradually increasing load. The time factor in plastic deflection readings is not at present considered, but, in general, tests were taken at uniform loading rates.

Curve OA, Fig. 1, represents the usual type of relationship between the load and the deflection in transverse. If at a suitable small load, say 0.1 ton, the total deflection is noted and the load removed, a small deflection remaining, the permanent set for that load can be observed. If this is repeated for a gradually increasing load, the curve OB can be drawn, connecting the load and the permanent set, as well as OA, connecting the load and the total deflection. The difference at each load between the total deflection and the permanent set is the elastic deflection for that load, and is shown by the curve OC. The author has found that in the course of several hundred tests, for a wide variety of irons and shapes and sizes of bar, the line OC is generally straight. In a small number of cases the line bends slightly towards the deflection axis, but for practical purposes it can be regarded as straight. A number of tests on tensile pieces with an extensometer taken in a similar way, show a similar slight curve, but further consideration of these results is deferred. The elastic deflection line does not always pass through the origin, but is usually close to it.

Table II.—*Mechanical Properties.*

Iron and Fig. No.	Tensile strength. Tons per sq. in.	Transverse strength. Tons per sq. in.	Total deflection. Mils.	Set. Mils.	Elastic deflection. Mils.	Brinell hardness. 3,000/10/30.	Impact blows to fracture.
1	28.7	50.0	353	80	273	277	2,886
2	—	13.4	125	12	113	210	38
3 & 5	14.9	28.6	209	46	163	211	495
4	—	29·0	880	700	180	139	3,923
7	20.4	46.8	1,163	1,042	121	156	—
8*A*	—	65.5	847	797	50	143	—
8*B*	—	50.5	478	443	35	137	—

The point of the arrow on the curve OA indicates the load and total deflection at fracture. The permanent set corresponding to the load at this point cannot, of course, be observed directly, but can be determined by a very simple construction.

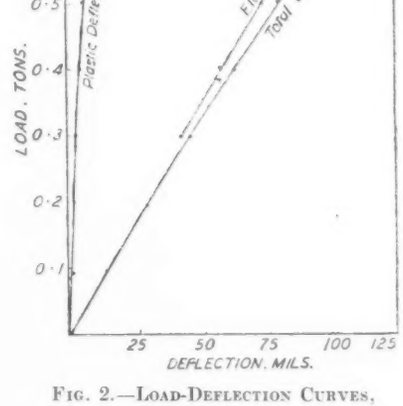

Fig. 2.—Load-Deflection Curves, Ferritic Iron.

If C represents the last point obtained on the elastic deflection line OC, OC is continued to cut AY in P. If YP be regarded as the elastic deflection corresponding to the breaking load OY, then AP represents the permanent set. YQ is marked off equal to AP, and BQ completes

* A Paper read before the Iron and Steel Institute.

OB to represent OQ, the load-set curve to fracture, just as OP represents the load/elastic-deflection curve to fracture. If the iron breaks very close to the previous load and set reading, as in Figs. 2 and 4, the construction is not necessary. It is not necessary to draw OA or OQ, for in most cases it suffices to draw the

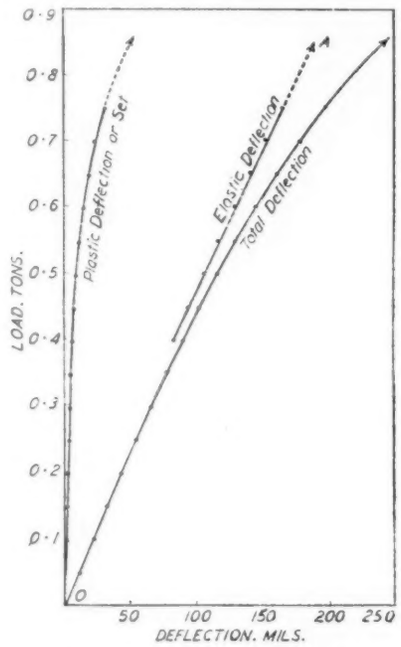

Fig. 3.—Load-Deflection Curves, Engineering Iron.

elastic deflection line OP, any point on which, of course, bears a linear relation to the applied load.

The curves OA, OP and OQ were actually obtained for the high-quality pearlitic iron of the modern inoculated type, the analysis of which is given, with those of other irons referred to in this Paper, in Table I. Some mechanical properties of these irons are given in Table II; for these the transverse rupture stress is calcu-

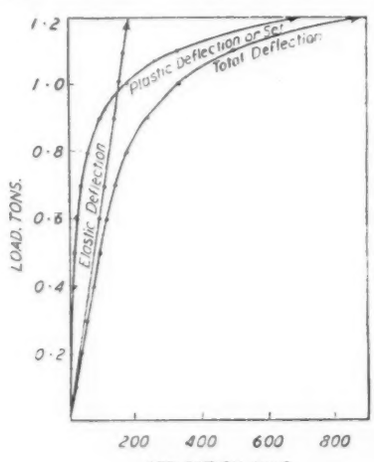

Fig. 4.—Load-Deflection Curves, Ductile Austenitic Iron.

lated from the usual beam formula for the rupture modulus, as recommended by the author in a previous Paper.[1] The impact test is a repeated-blow test of the Stanton type with a rounded notch, the energy input of each blow being 0.48 ft.-lb. The single-blow impact test, notched or unnotched, is not suited to cast iron, and the fatigue test cannot yet be conducted as a routine test. The repeated-blow test is a compromise which for laboratory purposes has certain advantages and which is inserted in view of the bearing of the energy of rupture, discussed below, on the impact strength.

While Fig. 1 represents a high-quality iron (No. 1), the results shown are characteristic of its class. Fig. 2 shows similar curves for a ferritic iron of somewhat brittle character (No. 2), Fig. 3 an ordinary quality engineering iron (No. 3), and Fig. 4 a relatively ductile iron of the new austenitic type (No. 4), which has a definite elongation in the cold state. In view of the connection between the deflection and the structural character of the metal, micrographs of the four irons mentioned are given in Figs. 10 to 13.

Table III.

Bar.	Test.	Total deflection *D*. Span. In.	Total deflection *D*. Mils.	Permanent set *S*. Mils.	Elastic deflection *D*–*S*. Mils.
1	2 × 1 in. vertically ..	36	350	55	295
2	Do. do.	12	62	12	50
3	2 × 1 in. flat ..	36	684	115	659
4	Do. do.	12	110	23	87
5	1 in. square ..	18	210	25	185
6	Do. do. ..	12	90	15	75
7	Do. do. ..	9	54	12	42

The deflections, elastic, plastic and total, of commercially available irons will, in general, fall between the extremes represented by Figs. 2 and 4, and irons of similar total deflections may have differing ratios of the two components. A rigid iron has a low set, and approaches more nearly to the truly elastic condition, while a ductile iron has a high set. Raising the set naturally increases the elastic deflection.

The load/elastic-deflection line is straight irrespective of the size or shape of the bar, or the span, or whether the bar is machined or not, or of the shape after machining in relation to the cast shape. It has been examined on the same material, for instance, in round bars, square bars, round machined from square, rectangular bars tested vertically and horizontally, and T-bars machined from the rectangular. Fig. 5 shows, in addition to the elastic deflection line OA for the 1.2-in. dia. bar shown in Fig. 3, OB, OC and OD, being load/elastic-deflection curves for a 2-in. by 1-in. bar tested vertically at 36-in. centres, a similar bar tested flat, and a 1-in. square bar at 18-in. centres (No. 3).

Table IV.

Bars.	Span ratios.	Ratios of total deflections *D*.	Ratios of sets *S*.	Ratios of elastic deflections.
1 & 2	3.0	5.6	4.6	5.9
3 & 4	3.0	6.2	5.0	6.5
5 & 7	2.0	3.9	2.0	4.4
5 & 6	1.5	2.3	1.7	2.5
6 & 7	1.33	1.6	1.2	1.8

Annealing the bar at, say, 400 deg. C. or 500 deg. C. for, say, 5 or 8 hrs. makes little difference to the set and deflection at fracture. Whilst internal stresses may be removed, annealing cannot heal or close the graphite cavities, and, indeed, annealing which results in a structural breakdown of pearlite and cementite to ferrite will thicken up the graphite.

Deflection and Span

In an ideal elastic beam the stress f is given by the usual beam formula $WL/4Z$, and the deflection D within the elastic limit by $WL^3/48EI$, where W is the load, L the span, E Young's modulus, and I and Z are the moment of inertia and the modulus of the section. Under these conditions the product WL is constant, and if the span L increases the load, W decreases, and *vice versa*. In the case of cast-iron beams, the author has previously shown that the transverse rupture stress at fracture is not constant for beams otherwise similar, but of varying span. It increases as the span diminishes, and *vice versa*. Thus, iron No. 3, referred to in Fig. 3, when tested at 18-in. and 12-in. spans, respectively, in the ratio 3:2, broke at loads of 0.825 and 1.38 tons respectively in the ratio 2:3.35, the products being as 2:2.2.

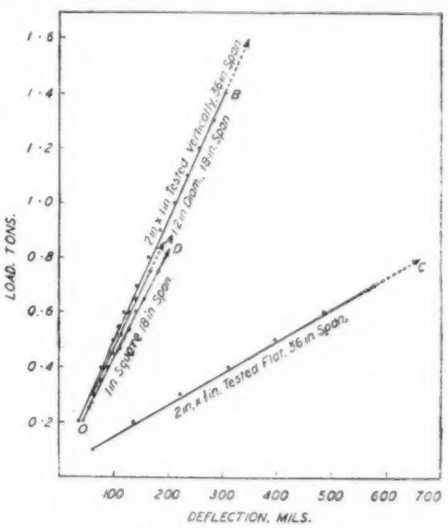

Fig. 5.—Elastic Deflection Curves.

For practical purposes the change in the rupture stress for small changes in span can be ignored, but the results for one span cannot without error be converted to those for a span materially different. For small changes WL can be regarded as constant. The elastic deflection in an ideal beam is directly proportional to the square of the span. If the span is doubled, the deflection is quadrupled. In a transverse test the formulæ cease to be valid, since the elastic limit is passed. The deflections found in practice seldom approach that anticipated from the formula. Table III gives for three bars of the same metal, tested under varying spans, the total and elastic deflection figures and the set. Table IV gives the actual ratios obtained. The iron is that referred to in Fig. 3 (No. 3).

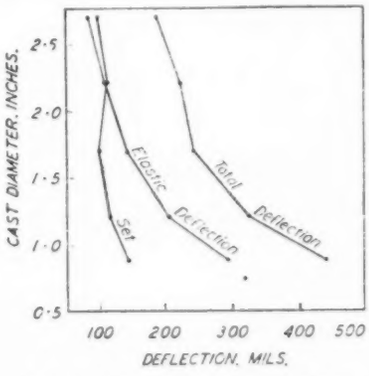

Fig. 6.—Deflection and Diameter.

The total deflection ratios do not approach that theoretically expected. The ratios of elastic deflection do so more nearly, and in the square bar slightly exceed it.

Deflection and Size and Shape of Bar

The deflection of an ideal elastic beam is inversely proportional to the cube of the depth in a rectangular, and as the fourth power of the diameter in a round beam. Differences in shape which do not modify the depth make little difference to the deflection. Thus, a 1-in. square

bar gave a total deflection at fracture of 270 mils and a set of 60 mils. A round bar machined from a similar square bar gave a total deflection at fracture of 285 mils and a set of 60 mils. With respect to change in depth or diameter, in practice the change in the deflection at fracture does not approach that anticipated from theoretical considerations. There is, however, no doubt that the deflection increases as the size of the bar diminishes. There is a practical

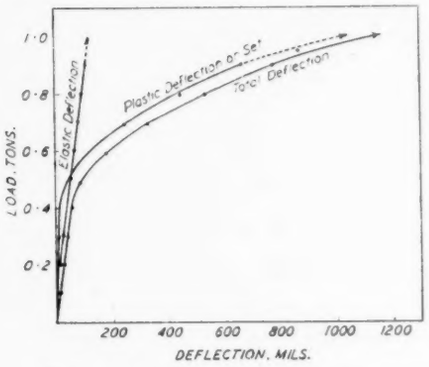

Fig. 7.—Load-Deflection Curves.

limit for this, for below a certain diameter the bar ceases to be grey and its behaviour is not considered further here. The actual deflections of a series of bars (iron No. 6) of varying diameters are given in Table V for a constant span, 18 in. The change in the transverse rupture stress is also given. Fig. 6 shows the changes. These curves are the loci of deflections on a series of bars of the same material varying in diameter.

Table V.

Dia. In.	Set *S*. Mils.	Elastic deflection *E*. Mils.	Total deflection *D*. Mils.	Transverse rupture stress. Tons per sq. in.
0.875	146	295	441	32.9
1.2	119	207	326	29.4
1.7	101	144	245	26.3
2.2	115	111	226	23.8
2.7	102	88	190	21.7

Whilst the set is not constant, the elastic deflection shows a smooth curve. Over a limiting diameter there is little or no change in the deflection figure.

Modulus of Elasticity

Young's modulus is notoriously difficult to determine for cast iron. In most load-deflection or load-extension curves it is generally assumed that the first portion of the curve is straight, and a tangent is drawn on the assumption that the point at which the curve leaves the tangent marks the beginning of permanent set. Unfortunately, in many cast irons no part of the curve is straight and this procedure leads to results which are only of approximate value. A tangent drawn to the curve at the origin also yields a result of only limited value.

These difficulties have led to various methods of procedure. In the United States the so-called "ultimate" modulus is often calculated,[2] using in the above-mentioned beam formula, $E = WL^3/48DI$, the total deflection D. As shown above, this value contains a very varying plastic component, and such a calculation is nearest the truth for very rigid irons. An alternative is to calculate E from the total deflection at an arbitrarily chosen fraction of the breaking load, one-quarter, or one-half, which is equivalent to assuming that the load-deflection curve is straight up to this load. If the chosen value be regarded as the working stress, the result becomes the so-called secant modulus. The proposal has been made in France that, instead of imposing a minimum deflection at fracture, transverse test specifications should call for a maximum deflection at a specified load within the breaking load, which is equivalent to restricting the permanent set.

Another serious objection to the conventional method of drawing a tangent to the curve arises from the fact that even where the first part of the curve is virtually straight, the readings contain some permanent set, and hence the fundamental assumption that the deflections under these conditions are wholly elastic is violated. In the method described above for separating the elastic and plastic deflections, it will be noted, for instance, in Figs. 1 to 4, that the elastic deflection curve is never tangential to the load/total-deflection curve, since there is a small permanent set even at low loads. The method of drawing a tangent is, therefore, not capable of giving accurate results. It will be shown below that irons so closely approaching elastic materials as malleable cast irons, give permanent sets at low loads which interfere with the tangent method, and the same appears to be true of steels. These objections do not apply to the use of the elastic deflection at fracture, and it is suggested that this basis be used in elastic modulus calculations for cast iron.

Table VI gives for the irons represented in Figs. 1 to 4, the elastic modulus in millions of

Table VI.

Iron and Fig. No.	*E*. Lb. per sq. in. $\times 10^{-6}$. Elastic deflection.	*E*. Lb. per sq. in. $\times 10^{-6}$. Total deflection.	*E*. Lb. per sq. in. $\times 10^{-6}$. Tangent.
1	19.6	15.1	—
2	10.7	9.65	—
3	18.0	14.0	—
4	15.6	3.18	—
7	23.2	—	19.6
8*A*	20.5	—	11.5
8*B*	22.5	—	7.7

pounds per square inch, based on the elastic deflection at fracture, and also the "ultimate" modulus based on the total deflection at fracture. The less permanent set the iron has, of course, the smaller is the difference, but a modern ductile iron (such as No. 4) shows a great difference, and an ordinary iron one of over 20 per cent. The

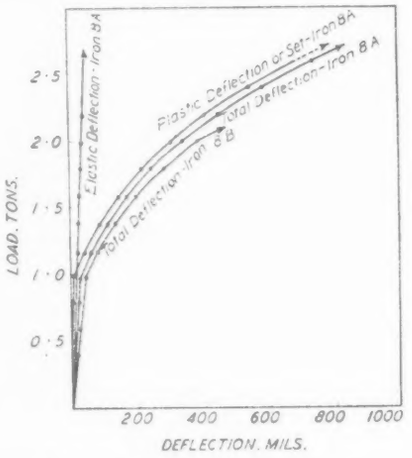

Fig. 8.—Load-Deflection Curves.

tangent method cannot be used where the initial part of the curve is not straight.

The use of the elastic deflection at fracture appears to have a good deal of justification, and to offer a more rational basis for calculation than alternatives hitherto used. The comparison of different irons becomes much more practicable. The elastic deflection at fracture can, in fact, be regarded in cast iron as comparable with the yield in the case of steels and wrought iron, to guard against reaching which a suitable factor of safety is used in engineering design.

Malleable cast iron, black-heart or white-heart, is a cast product which has elongation properties intermediate between those of the cast irons and the steels. The latter are graphite free, the irons contain flake graphite, while the malleable irons contain nodular graphite, so-called temper carbon. Fig. 7 shows the load-deflection curves for a white-heart malleable iron (No. 7), 0.8 in. in dia.,

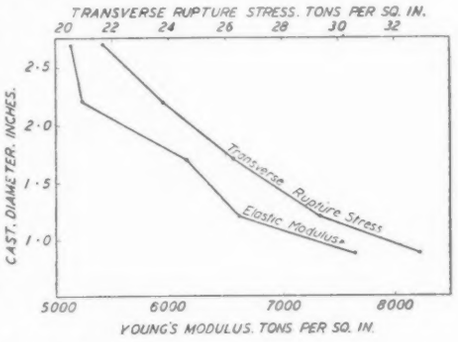

Fig. 9.—Effect of Diameter on Young's Modulus and Rupture Strength.

tested at 12-in. centres. The metal in the cast state, before annealing, would behave in this test like a very brittle steel, without set and with a low breaking load. The elastic-deflection line is again straight, and there is considerable plastic distortion even at low loads. The first part of the curve is straight to a load of 0.4 ton, the deflection at this load giving the tangent value of E. This, with the elastic-deflection value, is given in Table VI.

Table VII.—*Influence of Graphite on Elastic Deflection.*

Iron.	Breaking load. Tons.	Total deflection. Mils.	Set. Mils.	Elastic deflection. Mils.	*E*. Lb. per sq. in. $\times 10^{-6}$. Elastic deflection.
A	0.78	265	87	178	19.1
B	1.1	300	115	185	26.0

Fig. 8 shows similar curves for a laboratory-made white-heart malleable iron marked 8A. A portion of the same metal was treated while molten with a ladle graphitiser and annealed at the same time (No. 8B). This has had the effect of changing the pearlite, ferrite, temper carbon structure of the malleable iron (shown in Fig. 14) into pearlite and fine flake graphite (Fig. 15). The load/total-deflection curve is given in Fig. 8 and marked 8B. The set and elastic deflection curves are not reproduced for 8B, as up to the breaking load of 2.1 tons the elastic deflection line 8B lies virtually along the same line as for 8A and the set line 8B coincides with the total deflection line 8A. It will be observed that the change in the form of the graphite has not affected the slope of the elastic deflection line. The total deflection, however, increases more rapidly and is greater at all loads in 8B, which suggests that the set is due to a crushing effect at the cavities themselves.

The principal effect, however, is a marked reduction in the breaking load, which, of course, materially reduces E, but which is, nevertheless, higher than in the best grey irons, as in Fig. 1. This has been confirmed in another way. By a process of graphite refinement it has been possible to reduce the size of the individual flakes in high-carbon grey iron without change in the normal elements present. The effect of this, in general, is to increase the breaking load. The deflection is not greatly changed, but more results are required before a definite conclusion can be reached as to whether it is increased or decreased. The refinement of graphite brings

about a marked increase in E by virtue of the increased breaking load. A characteristic case is given in Table VII, which shows two irons, A ordinary, and B graphite-refined, otherwise similar.

There is ground for believing, therefore, that the reduction in size and quantity of the graphite increases the modulus of elasticity E throughout the whole range of cast irons. Thum and Ude[3] established this in the reverse direction by demonstrating the fall in E in steel plate artificially notched to simulate the effects of graphite.

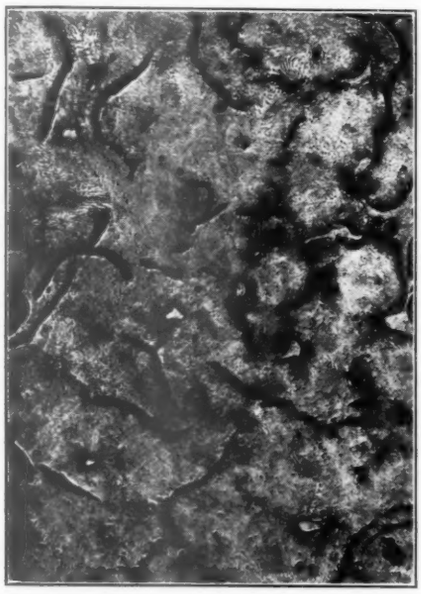

Fig. 10.—High-Quality Iron. Etched. ×200.

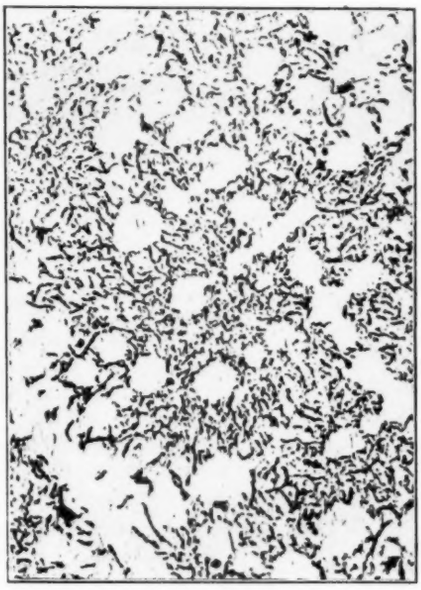

Fig. 11.—Ferritic Iron; somewhat Brittle. Etched. ×200.

Fig. 12.—Engineering Iron of Ordinary Quality. Etched. ×200.

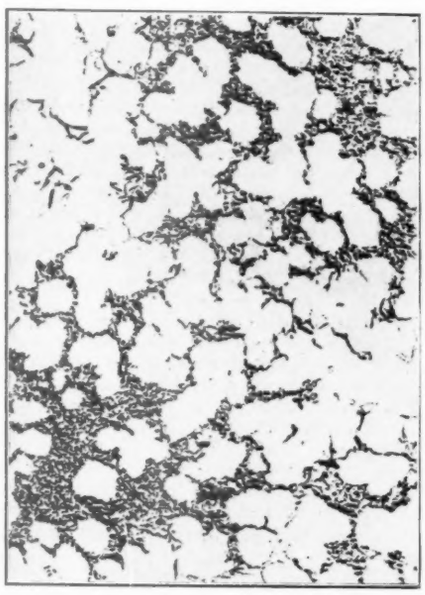

Fig. 13.—Austenitic Iron; relatively Ductile. Etched. ×200.

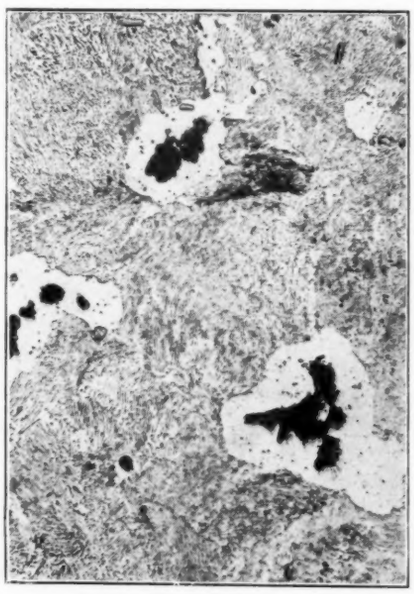

Fig. 14.—White-heart Malleable Iron, Untreated and Annealed (8a); Structure of Pearlite, Ferrite and Temper Carbon. Etched. ×200.

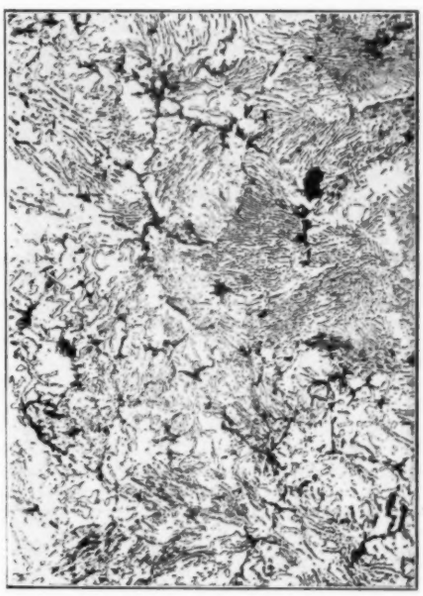

Fig. 15.—White-heart Malleable Iron, treated with Ladle Graphitiser and Annealed (8b); Structure of Pearlite and Fine-Flake Graphite. Etched. ×200.

It is necessary that E be determined on a standard bar, for, like the transverse rupture stress, it increases as the size of bar being tested falls. Fig. 9 shows the change of E with the diameter for the same iron (No. 6). The change in transverse rupture stress for the same series of bars is also given. For elastic beams the ratio of the transverse stress f to the elastic modulus is constant, for f/E can readily be shown to be equivalent to $6Dd/L^2$ for rectangular bars of depth d or round bars of diameter d. The elastic modulus E is therefore influenced by changes in section in much the same way as the transverse rupture stress.

Resilience

The calculation of E based on the breaking load and elastic deflection at fracture serves as a criterion for irons with respect to the elastic properties. The elastic deflection, however, varies so little that the value is governed mainly by the breaking load. In general, a brittle iron will be found to have a low permanent set and a tough iron a high permanent set. Measurements analogous to those of resilience, based essentially on the product of the breaking load and deflection, offer a convenient means of differentiating between tough and brittle irons. The area under the elastic deflection line may be regarded as the elastic resilience, representing the work done to the point of fracture, measured by one-half the product of the breaking load and elastic deflection. The area under the total deflection curve may be regarded as the energy of rupture, the total work done in breaking the bar. It is best determined by a planimeter. If the load be released short of fracture, the part of the work done represented by elastic strain, termed elastic resilience, is recovered, while the remaining part of the energy of rupture is represented by work done in plastic distortion, and is irrecoverable. Table VIII gives for some of the irons described the elastic

resilience and energy of rupture. The energy of rupture succeeds in placing these irons approximately in their order of toughness. For purposes of the calculation, the scales used in the diagrams are used. A relation might be expected to exist between the resilience measurement and the impact strength. At this stage no relationship is suggested with the particular impact test used, but the provision of further data should enable such a relation to be evolved.

The energy of a dynamic blow is dissipated in various ways other than in fracturing the test-piece and is consequently in excess of the energy expended in static fracture.

Much work has been done during the past few years on the establishment of more satisfactory criteria for the evaluation of the properties of cast iron. Comparison between work done abroad and that done in this country is difficult because of the necessity for working internationally on a standard bar, not yet achieved, although very satisfactory progress towards this is being made. Reference to some American work has already been made. In Germany, Thum and Ude[3] propose that the transverse rupture stress be divided by the total deflection at fracture, and suggest that the value so obtained can be correlated with the graphite structure. Meyersberg[4] proposes the use of the reciprocal value of the total deflection divided by the rupture stress. This value multiplied by 100 he calls the bending number, and the product of the bending member and tensile strength the bending product. Tensile strengths are plotted against the bending number.

In this country useful work has been done by Vivian[5] in drawing attention to the inadequacy of Hooke's Law as a basis for dealing with structural materials like castings, and to the possibility of reconciling, by proper theoretical consideration, such apparent inconsistencies as the difference between tensile and transverse strengths.

Since the total deflection comprises the two components, elastic and plastic deflection, each of which plays its part in determining the behaviour of the metal under stress, it seems essential that new criteria should treat these components separately. Furthermore, bearing in mind the nature of the material, by suitable adaptation of the principles of the strength of materials, such criteria can be evolved.

The suggested procedure for determining the elastic and plastic deflections has the merit of simplicity, and offers no special difficulty in routine testing. The breaking load on a standard bar is usually known approximately from experience. The load can be applied in the ordinary way, to a value of, say, 75 per cent. of the expected breaking load, and the deflection measured. The load can then be removed and the set observed. This procedure can then be repeated for loads of 80. 85, 90 per cent. and so on, until fracture. A sufficient number of points can then be obtained on the elastic deflection line to enable the proportions of these components in the total deflection at fracture to be determined.

Table VIII.—*Elastic Deflection Energy of Rupture.*

Iron and Fig. No.	Breaking load. Tons.	Total deflection. Mils.	Permanent set. Mils.	Elastic deflection. Mils.	Elastic resilience. In.-tons.	Energy of rupture. In.-tons.
1	1.59	353	80	273	0.22	0.32
2	0.71	125	12	113	0.04	0.05
3	0.85	247	55	192	0.08	0.12
4	1.20	880	700	180	0.11	0.84

Conclusion

In considering criteria which define the properties of grey cast iron under stress, it is necessary to work on standard bars tested under standard conditions. The deflection at fracture in transverse comprises:—(1) A part directly proportional to the applied load, and termed the elastic deflection, since during testing it disappears on the removal of the load; and (2) a part which increases more rapidly than the applied load, and termed the plastic deflection, or set, since it remains after the removal of the load.

The elastic deflection differs comparatively little from iron to iron, but irons differ widely in plastic deflection. Brittle irons are characterised by a low permanent set and tough irons by a high permanent set. As the section varies, however, the set is relatively constant, and the elastic deflection increases with the diameter.

In order to overcome difficulties arising from existing methods of determining the elastic modulus E for cast irons, and to offer a more satisfactory basis for the comparison of their elastic properties, it is suggested that E be calculated on the elastic deflection at fracture of a standard bar. Thus, the point of fracture of cast iron would be regarded in the same way as the limit of proportionality in wrought materials. The reduction in size and quantity of the graphite results in an increased elastic modulus, mainly by virtue of the increased breaking load. The elastic modulus, like the transverse rupture stress and other mechanical properties, increases as the size of the cast section tested diminishes.

In order to differentiate more satisfactorily between tough and brittle irons, it is suggested that the work done to the point of fracture, called the energy of rupture, be used. The work done to the point of fracture in causing elastic strain can be readily calculated, since the elastic deflection line is straight, as half the product of the breaking load and elastic deflection. The work done in both elastic and plastic strain, the energy of rupture, can best be determined by measuring the area under the total deflection line. The work done in plastic strain is then the difference between the two.

The accumulation of such data on irons used in practice by those who have the opportunity for testing and investigation would demonstrate more precisely than is at present known the influence on the deflection of the composition, structure, changes in size and quantity of the graphite, annealing and other treatment, and would assist in the more accurate specification of cast irons to meet the services they are called upon to perform.

The author thanks the Council of the British Cast Iron Research Association for permission to publish this Paper, and various members, too numerous to mention individually, for test-pieces from which some of the illustrative examples have been drawn.

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Report of Sub-Committee on Cast Iron

The last two paragraphs of the discussion on the Report of the I.B.F. Sub-Committee on Cast Iron, printed on page 45 of our issue July 19, should have been attributed to Mr. R. G. Tucker, B.A. (Member) instead of Dr. Donaldson. We sincerely regret this mistake should have occurred and tender our apologies to both contributors to the discussion.

The Routine Analysis of High Sulphur Steels

By Leonard D. Hewitt, Assoc.M.C.T.

The objections raised by steel users to the presence of sulphur have been much modified in recent years. For many classes of work it has been found that the addition of considerable amounts of sulphur has no apparent detrimental effect, and possesses the great advantage that much higher speeds of machinery can be employed without "plucking" of the metal. These "free-cutting" steels, as they are termed, contain commonly up to 0.15 per cent. of sulphur, and recently a class of steel, known as "super-free cutting," and containing up to 0.25 per cent. sulphur, has become widely used for lightly-stressed parts.

It is to the analysis of these types of steel that attention is here drawn. As a rapid routine test for sulphur, the "evolution" method is popular—that is, the evolution of the sulphur as sulphuretted hydrogen, its precipitation as a sulphide, and a subsequent iodine titration. This method, whilst giving fairly reliable results with low-sulphur steels, is much less satisfactory when used with "free-cutting" steel. The gravimetric method, however, is too lengthy for ordinary routine work, and the following modification of the "evolution" method will be found to give results comparable with the gravimetric test, even with 0.25 per cent. sulphur.

The solutions required are:—Iodine, 3.94 grams per litre, dissolved with the aid of potassium iodide in the usual way, and a stock solution of cadmium acetate, 50 grams dissolved in water, 250 c.c. added of ammonia, 0.880 specific gravity, and the solution made up to a litre with water. The iodine should be checked against an equivalent solution of sodium thiosulphate (crystalline) containing 12.4 grams per litre.

2.5 grams of steel turnings are weighed into a 500-ml. conical flask, fitted with a thistle funnel and delivery tube. The latter dips into an ordinary cylindrical gas jar, containing 20 c.c. of the stock cadmium-acetate solution, diluted to 100 mls. with water; 100 mls. of a 50 per cent. solution of hydrochloric acid are poured through the thistle funnel, and heat applied to the flask. The rate of heating is important, and should be such that the acid boils only immediately after the complete solution of the metal. The jar is then removed, together with the delivery tube, and 30 mls. of concentrated hydrochloric acid added, sufficient to dissolve the excess of ammonia and the cadmium sulphide. The containers are then poured into a No. 7 glazed porcelain dish, the jar washed out with plenty of water, and the washings added to the dish (a fairly dilute solution tends to greater accuracy). A little starch solution is added, and the solution titrated with the standard iodine solution, the end point being taken when a blue is obtained with no trace of purple.

The factor, according to the equation $H_2S + 2I = 2HI + S$, is 0.020, but this applies only to low-sulphur metal. The following factors will be found to give results comparable with the gravimetric method:—0.05 per cent. maximum, 0.020 factor; 0.05 per cent. to 0.10 per cent., 0.021 factor; 0.10 per cent. and upwards, 0.022 factor.

It will be seen that the last-named factor includes practically all steels of the "free-cutting" type. The reason for the increase of the factor is that high-sulphur metal gives low results by the evolution method. The factors can be checked by analysing various steels both gravimetrically and volumetrically.

The most important points are:—Rapid solution of the steel, with the use of only half the usual quantity of steel, 2.5 grams; the use of plenty of washing water to give a dilute solution for titration; and use of graded factor.

XUM

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This Week's News in Brief

Trade Talk

THE FALKIRK IRON COMPANY, LIMITED, have removed their Glasgow offices and warehouse from Bothwell Street to 41, St. Vincent Place.

THE INSTITUTE OF PATENTEES has changed its address from 39, Victoria Street to 10, Victoria Street, Westminster, London, S.W.1. No change has been made in telephone numbers or telegraphic address.

MESSRS. ALEXANDER FINDLAY & COMPANY, LIMITED, Parkneuk Bridge Works, Motherwell, have received large contracts for bridges which will keep the works employed to full capacity until the end of the year.

MESSRS. T. J. MORAN & COMPANY, LIMITED, Dublin, have secured the tender for the construction of a gate chamber at the entrance to the new dock extension now being carried out by the same firm at Limerick. The figure is £17,653.

THE BRITISH TIMKEN, LIMITED, of Birmingham, are at the present time delivering four 4-ft. 3-in. tapered roller bearings to be used in connection with a new rolling mill to be installed by the Renault Motor Car Company, of Belancourt, Paris.

ON AUGUST 9 Messrs. Scott's Shipbuilding & Engineering Company, Limited, Greenock, will launch the cruiser "Galatea" for the Admiralty. It is stated that electric welding has been employed more in her construction than in any other Admiralty vessel of her size.

THE DUBLIN PORT AND DOCKS BOARD invite tenders by August 14 for 70 Larssen No. 4 section sheet piles, 38 ft. long, of mild steel, with 0.25 to 0.35 per cent. copper content, about 61 tons in all; also 30 Larssen No. 2 section sheet piles, 38 ft. long, of mild steel, about 17 tons in all.

MESSRS. LITHGOWS, LIMITED, Port Glasgow, have received an order for a cargo steamer of 8,500 tons deadweight capacity from Messrs. Kaye, Son & Company, Limited, London, for one of their shipping companies. The machinery will be supplied by Messrs. David Rowan & Company, Limited, Glasgow.

MESSRS. BARCLAY CURLE & COMPANY, LIMITED, Glasgow, have booked an order to build a cargo steamer for British owners. The vessel will be 450 ft. in length, and the propelling machinery will be built by the firm at their North British Diesel Engine Works at Whiteinch. Work on the vessel is to start at once.

MR. LEONARD WALLS, of 41, Cheapside, London, E.C.2, has been appointed London agent for the Durex Manufacturing Company, 136, Rice Lane, Walton, Liverpool, 9, for the sale of Durex, a patternmaking material which assumes a stone-like appearance and for which freedom from expansion and contraction is claimed.

THE IRON TOLL BRIDGE crossing the River Severn at Ironbridge, which was cast and erected at Coalbrookdale in the years 1777-79 and is the oldest of large dimensions in this country, has been scheduled as an ancient monument, and is to be replaced by a new bridge. This decision was reached by the Salop County Council at its meeting at Shrewsbury last Saturday.

A BOILER CONTRACT valued at £750,000 has been obtained by Messrs. Babcock & Wilcox, Limited. The work will be carried out at the Renfrew and Dumbarton works, where over 5,000 men are already working night and day on urgent orders. Orders booked and in prospect ensure full employment for several months ahead. The firm is the busiest concern on the Clyde.

SOME TIME AGO the management of Messrs. Alder & Mackay, Limited, Edinburgh, gas-meter manufacturers, realised that they had many employees with 30 years' service or more with the company to their credit, and the directors decided to make some recognition. This has taken the form of an illuminated and framed long-service certificate, bearing the recipient's name and number of years of service as at June 30, 1934, and is signed by the chairman of the company, Mr. J. Miller Thomson.

CRANES CANNOT BE MADE in the Irish Free State. This fact emerged during a discussion at Dublin Port and Docks Board, when the Lord Mayor asked why the Board were buying second-hand cranes for use at the port. Mr. C. O'Kelly, the vice-chairman, who presided, then revealed that cranes could not be made in the country. He suggested that the Board go into committee on the matter, as the engineer had some suggestions to make.

MR. A. HAAG, of 30-34, New Bridge Street, London, E.C.4, has marketed a pattern mixture carrying the trade-mark "Warowa," for which the following claims are made:—(1) It gives a very faithful reproduction; (2) it is very plastic; (3) it is exceedingly hard; (4) the sand can be rammed on with pneumatic or electric hammers without risk of chipping; (5) it produces a very smooth surface, which reduces considerably the necessity of dressing the casting; (6) it retains its volume in that it does not contract or expand in the least; and (7) every pattern can be used many times; thousands of reproductions can be made from one pattern.

MESSRS. HARLAND & WOLFF, LIMITED, have launched from their Govan yard the "John Dock," one of the most powerful tugs ever built on the Clyde. The tug is the first of two being built for the South African Railways and Harbours Administration, and is specially designed for deep-sea towing and salvage work. The vessel is 145 ft. in length, with a breadth of 32 ft. She has five watertight bulkheads, double bottom and deep tanks for fresh water, boiler-feed water and water ballast. The propelling machinery consists of two sets of triple-expansion engines supplied with steam from Babcock & Wilcox water-tube coal-fired boilers. The machinery is designed to develop 2,600 i.h.p.

A GENERAL RESTART was made in the Motherwell district at the beginning of last week, under somewhat cheering conditions. The orders at the steelworks are fairly numerous, and it is expected that by the end of the week the full complement of furnaces will be in operation at Messrs. Colvilles' Dalzell Works. Work in all the heavy industries is brisk. Messrs. Alex. Findlay's Parkneuk Bridge Works will be kept busy for many months. Messrs. Hurst Nelson's wagon works are also well employed, whilst Messrs. Anderson & Boyes, Limited, Flemington, have had to resort to a night shift in order to undertake the volume of work they have on hand for electrical engineering and coal-mining machinery. Generally, the industrial situation in Motherwell district gives rise to brighter prospects for the future.

THE INDUSTRIAL COURT in London has issued its award regarding an application made by the National Union of Railwaymen and the National Union of Foundry Workers with reference to the rate of pay of four moulders employed in the foundry of the L.M.S. Railway Company, at their St. Rollox Works, Glasgow. The men were employed as machine moulders at the rate of 38s. per week, and the unions claimed that the correct rate of pay was 48s., the hand-moulders' rate. The company's view was that the men were employed on moulding machines and that they had accepted employment as machine moulders at 38s. per week. The Court found that the men entered into a contract of employment as machine moulders and were so employed, and that 38s. per week was in accordance with the provisions of the award.

Contracts Open

Sandwich, August 7.—Supply and laying 533 yds. 6-in. cast-iron gas main. Mr. J. Giles, manager, Gas Works, Sandwich. (Fee £1, returnable.)

Buenos Aires, August 29.—Turret lathes for the quantity production of iron and brass parts, for the Argentine State Railways Administration. The Department of Overseas Trade. (Reference A.Y. 12,507.)

Carnalbanagh, August 9.—Providing and laying about 450 lineal yds. 2-in. water pipe at Carnalbanagh, Glenarm, for the Larne Rural District Council. Mr. S. Robinson, engineer, Victoria Street, Larne.

Bray, August 7.—Providing and laying about one mile 8-in. water main, with air valves and sluice valves, for the Urban District Council. Mr. S. MacCathmhaoil, town clerk, Town Hall, Bray, Co. Wicklow. (Fee £2 2s., returnable.)

Crowland, August 14.—Construction, completion and maintenance of about 5,900 yds. 6-in., 920 yds. 4-in., and 7,660 yds. 3-in. cast-iron pipes, with sluice valves, etc., for the Spalding Rural District Council. The Council Offices, Spalding, or Messrs. Silcock & Simpson, 25, Victoria Street, Westminster, S.W.1, and 10, Park Row, Leeds, 1. (Fee £5, returnable.)

Personal

MR. STANLEY E. DAWSON, F.I.C., has been appointed chief metallurgist to the Stanton Ironworks Company, Limited, near Nottingham.

ON THE OCCASION of his retirement after 43 years' service with Glenfield & Kennedy, Limited, Kilmarnock, Mr. Lewis Sheddon, foreman ironmoulder, was presented with an umbrella, along with a chair for Mrs. Sheddon, together with a wallet of Treasury notes. Mr. Gibb, in making the presentation, expressed the wish of all his colleagues that Mr. Sheddon would enjoy many years in retirement.

MAJOR C. E. WILLIAMS, C.B.E., chief inspecting engineer to the Crown Agents for the Colonies, retires this month after 30 years' service. Apprenticed at the Vulcan Locomotive Works, Newton-le-Willows, Lancs, Major Williams served from 1901 to 1904 as assistant manager of Robert Stephenson & Company, Limited, locomotive builders, of Darlington, and from 1904 to 1915 as deputy-chief inspecting engineer, Crown Agents for the Colonies. He became technical head of the engineering inspection department in 1919, and was appointed to his present position in 1922.

MR. BENJAMIN TALBOT (managing director and deputy chairman of the South Durham Steel & Iron Company, Limited, and the Cargo Fleet Iron Company, Limited) and Mrs. Talbot celebrated their golden wedding recently. To mark the event, Mr. and Mrs. Talbot entertained at Solberge Hall, near Northallerton, over 1,000 guests, representatives of the various companies with which Mr. Talbot is associated and representatives of the steel and iron trades at Saltburn, Middlesbrough, West Hartlepool and Stockton. Mr. and Mrs. Talbot were the recipients of numerous congratulatory messages and gifts.

Will

SIMPSON, M. L., formerly manager of the Steel Company of Scotland, Limited £19,696

Obituary

MR. ALAN WILLIAMS, melting-shop manager for Messrs. Steel, Peech & Tozer, Limited, for 17 years, died at his home in Rotherham recently.

MR. VICTOR WILLIAMS, chief draughtsman at the engineering works of Holman Bros., Limited, Camborne, died last Sunday, after a long illness, at the age of 53.

THE DEATH OCCURRED at his home in Glasgow, on July 15, of Mr. James Allan, foreman moulder of Messrs. Walter Macfarlane & Company's Saracen Foundry, Possilpark, Glasgow. Mr. Allan was in his 73rd year.

THE DEATH HAS OCCURRED of Mr. Reavely Oswald, a director of Messrs. Smith, Patterson & Company, Limited, ironfounders, of Blaydon-on-Tyne. He began his connection with the firm as an office-boy half-a-century ago, and after serving many years as secretary joined the management board eight years ago.

MR. H. J. SKELTON, for many years a well-known figure in the iron and steel trade, died on Sunday, July 22. Mr. Skelton was the founder, in 1883, of the firm of H. J. Skelton & Company, which was formed into a limited liability company in 1911, with Mr. Skelton as chairman. Prior to this date Mr. Skelton had already been very active in the steel trade in one direction or another. He was chairman of the Committee of Management of the London Iron and Steel Exchange for nine years from its formation in 1919. For twelve years he was a member of the Council of the London Chamber of Commerce, became chairman of the Iron and Steel Trade Section in January, 1920, and was a member of the General Purposes Committee until he resigned in 1932. Mr. Skelton was the author of "Economics of Iron and Steel," first published in 1891, and in a second edition, enlarged and illustrated, in 1924. This volume met with universal praise and appreciation from the entire trade, and is still widely used as an authoritative text-book and guide to the iron and steel trade. Mr. Skelton was regarded both on the Continent and in America, as well as at home, as a leading authority on iron and steel questions. He was a pioneer of the engineering standards movement in England, a movement which had the effect, according to the most competent authorities, of lowering the cost of British steel production with far-reaching benefit to the British trade. During the late war his services were much requisitioned by the Government.

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XUM

Raw Material Markets

Holiday conditions rule in the home iron and steel markets, and the volume of business is much reduced. Inquiries for autumn delivery are circulating but, with fixed prices operating for many grades of material, there is not the same incentive to book forward. Quotations are generally firm, and the producers take a confident view of the situation. Export business remains limited.

Pig-Iron

MIDDLESBROUGH.—The demand for Cleveland pig-iron has continued slack, owing to seasonal interruptions in the consuming trades, and the makers have had to make small additions to their unsold stocks. There is, however, no fear of the latter reaching unmanageable proportions, particularly now that work has been resumed at the Scottish foundries. The agreed minimum scale governs all home sales, No. 3 Cleveland G.M.B., the standard foundry grade, being quoted at 67s. 6d. per ton delivered Middlesbrough, 69s. 6d. delivered North-East Coast, 67s. 3d. delivered Falkirk and 70s. 3d. delivered Glasgow. For No. 1 Cleveland foundry iron 2s. 6d. more than the foregoing prices is quoted, and both No. 4 foundry and No. 4 forge iron are 1s. per ton less than No. 3 G.M.B.

East Coast hematite continues in heavy demand, as the production of steel in this country is still at a very high level. Export orders remain very hard to come by, in spite of the low quotations offered. Home prices are based upon No. 1 East Coast hematite at 68s. per ton delivered Middlesbrough, 70s. delivered Durham and Northumberland, 75s. delivered Scotland, 74s. to 77s. delivered Yorkshire and 79s. delivered Birmingham.

LANCASHIRE.—A slight expansion in contract buying has been noticeable on the Manchester Royal Exchange during the past week, and several purchases have already been made for delivery up to the end of the year. Forward sales are likely to show improvement this month, as a number of old contracts are shortly due to expire. Quotations are steady, with Lancashire iron equal to Derbyshire quality offered for delivery to users in the Lancashire zone at 74s. per ton, Derbyshire No. 3, Staffordshire and North-East Coast brands all quoted at the same figure, and Northamptonshire and Lancashire iron equal to Northants at 72s. 6d. Scottish ironmasters continue to report slow trading conditions in this area, but there has been no alteration in values, around 82s. 6d. per ton being indicated for delivery equal to Manchester. West Coast hematite, also, is quiet at about 80s. 6d., with East Coast material quoted at 76s. for No. 1 and 75s. for No. 3 grade, both unbroken.

MIDLANDS.—Pig-iron buying has been on the quiet side lately, seasonal influences having the upper hand. The Central Pig-Iron Producers' Association had its monthly meeting last week, when it was decided to make no change in quotations. The controlled prices of ordinary foundry iron, delivered Birmingham and Black Country stations, are 67s. 6d. per ton for Northants No. 3, and 71s. for Derbyshire, Lincolnshire and Staffordshire No. 3, these figures being subject to a small rebate to big consumers. At the present time a fair tonnage of special iron is going into consumption, and prices are firmly held, varying according to the quality involved. Medium-phosphorus iron is available at from 75s. to 80s., low-phosphorus iron, including Scottish, from 85s. to 87s. 6d., and special refined iron for engine work, etc., from £5 10s. to £6 15s., delivered this district.

SCOTLAND.—Business in pig-iron on the Glasgow market is now returning to more normal conditions, the holidays having come to an end. Orders are still scarce, however, particularly for Scottish No. 3 foundry, which is quoted at 70s. f.o.r. furnaces, with 2s. 6d. extra for No. 1. The light-castings trade continues to be very busy, and there is a steady call for Cleveland No. 3 at 67s. 3d. f.o.r. Falkirk and 70s. 3d. f.o.r. Glasgow. Other English irons are obtainable at slightly less.

Coke

There is no sign of any easiness developing in the foundry coke market. On the contrary, the ovens have maintained full spring prices during the slack season, no concessions being made. Indeed, an increase in values during the next month or so would not be surprising. Current quotations for delivery in the South Staffordshire area are as follow:—Best Durham foundry coke, 36s. to 40s.; Welsh coke, 37s. 6d. to 45s., according to analysis and tonnage; Scottish coke, 40s. to 41s. per ton.

Steel

Business has contracted on the approach of Bank Holiday, but there has been considerable activity at the works in order to get deliveries away before closing down, states the official report of the London Iron and Steel Exchange. In spite of quieter trading conditions, the market has a confident tone, and while there have been no recent increases in prices, the tendency is firm. There has been rather more activity in the semi-finished-steel department, and, although there have been some transactions in imported semis, the greater part of the business has been taken by British works. Competition from foreign sellers is making itself felt, and at times material has been offered, including duty, at prices which worked out at less than the home makers' quotations. In the finished-steel department, irregular conditions have developed, but for the most part the steelworks have good order-books which will ensure production being maintained during the summer holiday period. Export business has shown a tendency to increase, and a more active inquiry is reported from some overseas markets. The demand, however, is principally from the home trade, and considering the time of the year, the volume of business is not unsatisfactory.

Scrap

The demand for cast-iron scrap has continued to be affected by seasonal inactivity at the foundries. In the Cleveland area, 47s. 6d. for ordinary heavy cast iron and 50s. for machinery metal are the best prices obtainable. Scrap-iron prices in the Midlands, however, show no relapse, at 55s. delivered for heavy machinery metal, 50s. for good pipe and plate scrap and 47s. 6d. for clean, light cast iron. In Scotland, machinery cast-iron scrap, in pieces suitable for cupolas, has been sold in small parcels at about 55s., ordinary heavy cast-iron to the same specification being quoted at about 52s. 6d. There is only a limited demand for scrap iron in South Wales, where heavy cast iron is quoted at 45s. to 47s. 6d., light cast-iron scrap at 40s. to 41s. 6d. and heavy machinery metal at 50s. to 52s. 6d.

Metals

Copper.—Buying of this metal, as in the case of other commodities, has been affected by seasonal conditions. The demand from industrial consumers for electro metal has been irregular, and the total aggregate has been distinctly small. The European copper demand has naturally been affected by the disturbed course of political events. "Standard" quotations on the London market have weakened further, and are likely to remain low for some time.

Daily market prices:—

Cash.—Thursday, £29 3s. 9d. to £29 6s. 3d.; Friday, £28 18s. 9d. to £29 1s. 3d.; Monday, £29 1s. 3d. to £29 3s. 9d.; Tuesday, £28 16s. 3d. to £28 17s. 6d.; Wednesday, £28 13s. 9d. to £28 15s.

Three Months.—Thursday, £29 11s. 3d. to £29 12s. 6d.; Friday, £29 6s. 3d. to £29 7s. 6d.; Monday, £29 8s. 9d. to £29 10s.; Tuesday, £29 2s. 6d. to £29 3s. 9d.; Wednesday, £29 1s. 3d. to £29 2s. 6d.

Tin.—Reports from Europe and the United States indicate that the industrial demand for tin continues to be limited. Quotations on the London Metal Exchange have, however, been well maintained, the market being strongly supported by "pool" interests.

The July Bulletin of the International Tin Research and Development Council reveals the fact that the consumption of tin in the world's tinplate industry reached the highest figure recorded at 55,000 tons for the twelve months ending May, 1934, being 5,000 tons more than in 1929 and 2,800 tons more than in the peak year of 1933. World consumption of tin during the same 12 months showed an increase of 27 per cent. over the preceding year.

Price fluctuations:—

Cash.—Thursday, £231 10s. to £231 12s. 6d.; Friday, £231 7s. 6d. to £231 12s. 6d.; Monday, £231 5s. to £231 7s. 6d.; Tuesday, £231 5s. to £231 7s. 6d.; Wednesday, £229 to £229 5s.

Three Months.—Thursday, £231 7s. 6d. to £231 12s. 6d.; Friday, £231 7s. 6d. to £231 12s. 6d.; Monday, £231 5s. to £231 7s. 6d.; Tuesday, £231 5s. to £231 7s. 6d.; Wednesday, £229 to £229 5s.

Spelter.—The market has been rather dull. "In this country, the peculiar situation resulting from the tariff protection for Empire metal has led to the importation of some quantities of foreign spelter, as consumers have found it cheaper to purchase such metal and pay the 10 per cent. tariff. At the present low price the amount of the duty is not much higher than the premium paid by the trade," report Messrs. Brandeis, Goldschmidt.

Day-by-day quotations:—

Ordinary.—Thursday, £13 8s. 9d.; Friday, £13 8s. 9d.; Monday, £13 8s. 9d.; Tuesday, £13 10s.; Wednesday, £13 7s. 6d.

Lead.—The unsettled state of affairs on the Continent has, to some extent, disturbed the market for this metal. The demand from lead manufacturers in this country, however, has been quite good in view of the onset of the holiday season. Empire metal has been scarce, and a good premium has prevailed for any supplies available. This has resulted in the release of a certain amount of duty-free foreign metal from warehouse, also at a premium.

Price fluctuations have been as follow:—

Soft Foreign (Prompt).—Thursday, £11; Friday, £10 17s. 6d.; Monday, £10 18s. 9d.; Tuesday, £11 13s.; Wednesday, £10 17s. 6d.

Royal Metal Trades' Pension Society

MR. WATSON SLACK'S BROADCAST APPEAL

Last week, through the courtesy of the B.B.C., Mr. J. Watson Slack appealed for the Royal Metal Trades' Pension Society. This body was founded ninety-one years ago "for the relief of aged and necessitous non-manual members of the Metal Trades and widows of such persons." During this period it has helped 2,500 persons at a cost of £329,000. Undoubtedly this is a good record, but the metal trades should do more. There are thirty thousand firms in the trade, yet only five thousand subscribe. Last week the July election was held, and out of sixty-six candidates twenty were elected, so there are now two hundred and seventy pensioners. Forty-six candidates could not be accepted for lack of money, yet their incomes were but 10s. to 12s. a week. It was for them that Mr. Watson Slack pleaded and asked his listeners to realise that a member of the Committee has seen each one of them and really knew their circumstances and their urgent need.

We ask our readers who did not hear Mr. Watson Slack's broadcast appeal to supplement the amount so received by sending subscriptions to him at the Royal Metal Trades' Pension Society at 148, Edmund Street, Birmingham.

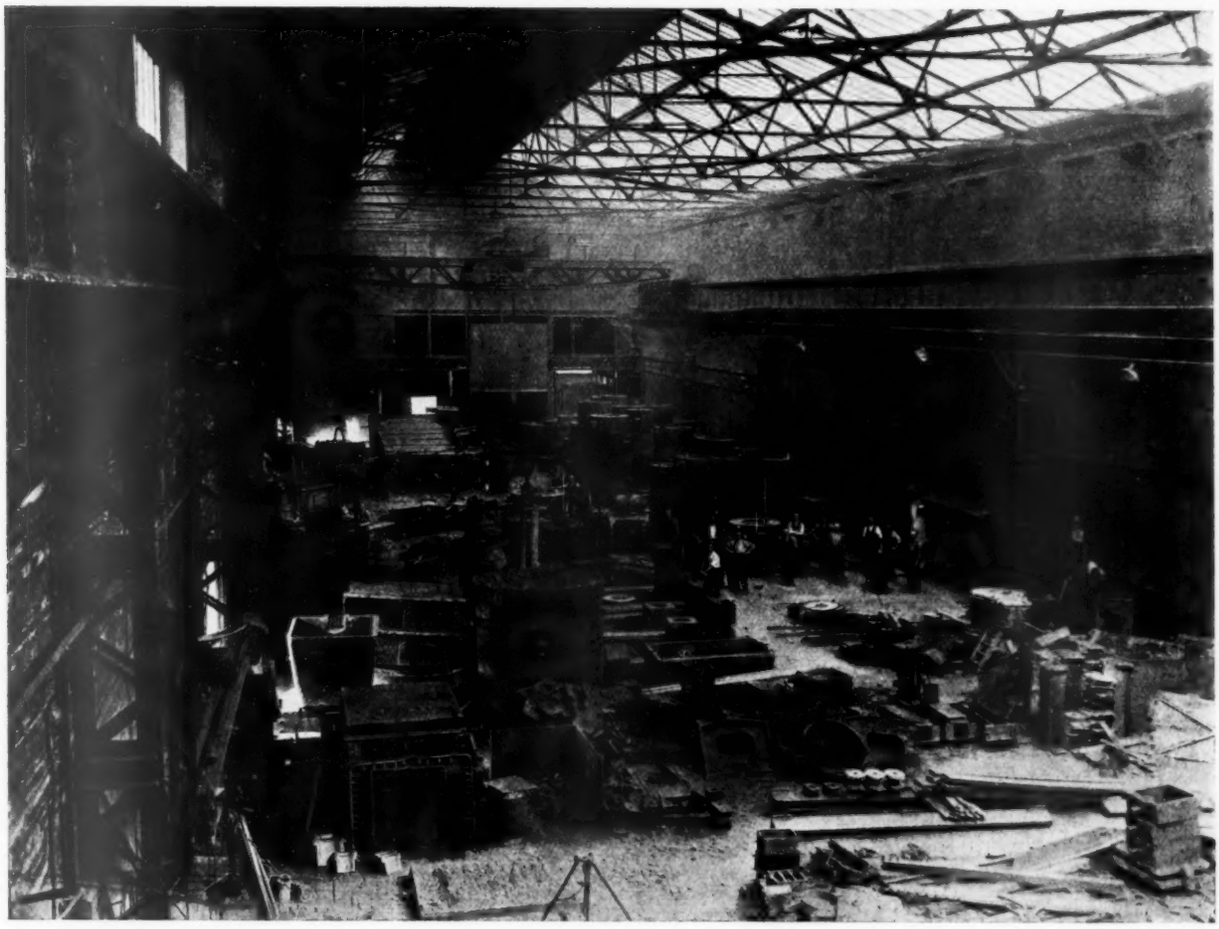
Roll Lathes

An article of considerable interest to roll founders appears on pages 9 to 11 in the current issue of the "Craven Machine Tool Gazette," which is issued by Craven Bros. (Manchester), Limited, Reddish, Stockport.

Further Experiments on Cylinder Wear

Mr. C. G. Williams, manager of the Research Department of the Institute of Automobile Engineers, has published in Report No. 7500B, Classes 42 and 57, the results of a research he undertook to investigate possible causes of corrosion at low temperatures, and he describes experiments he made to operate an engine on a nitrogen-free atmosphere. This particular research does not correlate any results with composition of the metal used in the engines.

BRITISH ROLL FOUNDRIES



Roll Foundry of THE LLANELLY FOUNDRY & ENGINEERING CO., LTD., LLANELLY, regular users of—

GENUINE
COLD BLAST PIG IRON

Our Brands are recommended for—

BEST QUALITY CHILLED CASTINGS.

HIGHEST GRADE WROUGHT IRON FOR *ALL TESTS.*

GENERAL CYLINDER WORK, AND CASTINGS REQUIRING STRENGTH, RESISTANCE TO ABRASION AND HEAT, AND MACHINING QUALITIES.

THE EARL OF DUDLEY'S ROUND OAK WORKS, LTD.
BRIERLEY HILL, STAFFS.
Brand: "DUD·L.N.F'ces:DUD"

M. & W. GRAZEBROOK, LIMITED
DUDLEY, WORCS.
Brand: "GRAZEBROOK"

THE LOW MOOR IRON CO., LTD.,
NEW WORKS, LOW MOOR, BRADFORD - YORKSHIRE
Brand: "LOWMOOR C.B."

XUM

RAW MATERIALS—PRICE LIST

(Wednesday, August 1, 1934)

COPPER

	£	s.	d.
Standard cash	28	13	9
Three months	29	1	3
Electrolytic	31	15	0
Tough	30	15	0
Best selected	31	5	0
Sheets	58	0	0
India	41	15	0
Wire bars	32	5	0
Ingot bars	32	5	0
H.C. wire rods	34	15	0
Off. av. cash, July	29	15	0
Do., 3 mths., July	30	2	1 1/11
Do., Sttlmnt., July	29	15	0
Do., Electro, July	33	0	0
Do., B.S., July	32	13	0 5/11
Do., wire bars, July	33	4	5 2/11
Solid drawn tubes			9½d.
Brazed tubes			9½d.
Wire			6¼d.

BRASS

Solid drawn tubes	8¾d.
Brazed tubes	10½d.
Rods, drawn	8½d.
Rods, extd. or rlld.	4½d.
Sheets to 10 w.g.	7d.
Wire	7½d.
Rolled metal	6½d.
Yellow metal rods	4½d.
Do. 4 × 4 Squares	5¾d.
Do. 4 × 3 Sheets	5¾d.

TIN

	£	s.	d.
Standard cash	229	0	0
Three months	229	0	0
English	229	5	0
Bars	231	0	0
Straits	229	10	0
Australian (nom.)		—	
Eastern	229	0	0
Banca	230	0	0
Off. av. cash, July	230	9	3 9/11
Do., 3 mths., July	230	1	5 7/11
Do., Sttlmt., July	230	8	10 4/11

SPELTER

	£	s.	d.
Ordinary	13	7	6
Remelted	14	5	0
Hard	11	5	0
Electro 99.9	16	0	0
English	14	5	0
India	13	5	0
Zinc dust	16	10	0
Zinc ashes	3	0	0
Off. aver., July	13	11	7 1/11
Aver. spot, July	13	9	3 9/11

LEAD

	£	s.	d.
Soft foreign ppt.	10	17	6
Empire (nom.)	11	11	3
English	12	15	0
Off. average, July	10	18	6 3/22
Average spot, July	10	16	3

ALUMINIUM

Ingots	£100 to £105
Wire	1/1 to 1/9 lb.
Sheet and foil	1/2 to 2/9 lb.

ZINC SHEETS, &c.

	£	s.	d.
Zinc sheets, English	23	5	0
Do., V.M. ex whse.	21	12	6
Rods	27	10	0

ANTIMONY

	£	s.	d.	£	s.	d.
English	40	0	0 to	43	0	0
Chinese, ex-whse.				36	0	0
Crude				24	0	0

QUICKSILVER

	£	s.	d.	£	s.	d.
Quicksilver	11	0	0 to	11	10	0

FERRO-ALLOYS AND STEEL-MAKING METALS

Ferro-silicon—	
25%	£8 17 6
45/50%	£13 0 0
75%	£18 7 6
Ferro-vanadium—	
35/50%	12/8 lb. Va.
Ferro-molybdenum—	
70/75% carbon-free	5/6 lb. Mo.
Ferro-titanium—	
23/25% carbon-free	9d. lb.
Ferro-phosphorus, 20/25%	£14 10 0
Ferro-tungsten—	
80/85%	3/3 lb.
Tungsten metal powder—	
98/99%	3/6 lb.
Ferro-chrome—	
2/4% car.	£29 15 0
4/6% car.	£23 0 0
6/8% car.	£21 12 6
8/10% car.	£21 12 6
Ferro-chrome—	
Max. 2% car.	£36 0 0
Max. 1% car.	£38 15 0
Max. 0.70% car.	£42 0 0
70%, carbon-free	10d. lb.
Nickel—99.5/100%	£200 to £205
"F" nickel shot	£184 0 0
Ferro-cobalt, 98/99%	5/3 lb.
Metallic chromium—	
96/98%	2/5 lb.
Ferro-manganese (net)—	
76/80% loose	£10 15 0 to £11 5 0
76/80% packed	£11 15 0 to £12 5 0
76/80% export	(nom.) £9 15 0
Metallic manganese—	
94/96% carbon-free	1/2 lb.

Per ton unless otherwise stated.

HIGH-SPEED TOOL STEEL

Finished bars, 14% tungsten	2s. 0d.
Finished bars, 18% tungsten	2s. 9d.

Per lb. net, d/d buyers' works.

Extras—

Rounds and squares, 3 in. and over	4d. lb.
Rounds and squares, under ½ in. to ¼ in.	3d. lb.
Do., under ¼ in. to 1/8 in.	1/- lb.
Flats, ½ in. × ¼ in. to under 1 in. × ⅛ in.	3d. lb.
Do., under ¼ in. × ¼ in.	1/- lb.
Bevels of approved sizes and sections	6d. lb.

Bars cut to length, 10% extra.

SCRAP

	£	s.	d.	£	s.	d.
South Wales—						
Heavy steel	2	13	6 to	2	15	0
Bundled shrngs.	2	5	0 to	2	7	6
Mixed iron and steel	2	8	0 to	2	10	0
Heavy cast iron	2	5	0 to	2	7	6
Good machinery	2	10	0 to	2	12	6
Cleveland—						
Heavy steel				2	10	0
Steel turnings				1	17	6
Cast-iron borings				1	7	6
Heavy forge				2	10	0
W.I. piling scrap				2	5	0
Cast-iron scrap	2	7	6 to	2	10	0
Midlands—						
Light cast-iron scrap				2	7	6
Heavy wrought iron				2	17	6
Steel turnings, f.o.r.				1	12	6
Scotland—						
Heavy steel	2	10	0 to	2	11	0
Ordinary cast iron				2	12	6
Engineers' turnings				2	0	0
Cast-iron borings				2	0	0
Wrought-iron piling				2	10	0
Heavy machinery				2	15	0

London—Merchants' buying prices, delivered yard.

	£	s.	d.
Copper (clean)	25	0	0
Brass	17	10	0
Lead (less usual draft)	9	10	0
Tea lead	7	0	0
Zinc	9	0	0
New aluminium cuttings	69	0	0
Braziery copper	22	0	0
Gunmetal	23	0	0
Hollow pewter	145	0	0
Shaped black pewter	110	0	0

PIG-IRON

N.E. Coast (d/d Tees-side area)—	
Foundry No. 1	70/-
Foundry No. 3	67/6
,, at Falkirk	67/3
,, at Glasgow	70/3
Foundry No. 4	66/6
Forge No. 4	66/6
Hematite No. 1	68/-
Hematite M/Nos.	67/6
N.W. Coast—	
Hem. M/Nos. d/d Glas.	72/6
,, d/d Birm.	84/6
Malleable iron d/d Birm.	115/-
Midlands (d/d Birmingham dist.)—	
Staffs No. 4 forge	67/-
,, No. 3 fdry.	71/-
Northants forge	63/6
,, fdry. No. 3	67/6
,, fdry. No. 1	70/6
Derbyshire forge	67/-
,, fdry. No. 3	71/-
,, fdry. No. 1	74/-
Scotland—	
Foundry No. 1, f.o.t.	72/6
,, No. 3, f.o.t.	70/-
Hem. M/Nos. d/d	71/-
Sheffield (d/d district)—	
Derby forge	64/6
,, fdry. No. 3	68/6
Lincs forge	64/6
,, fdry. No. 3	68/6
E.C. hematite	80/6
W.C. hematite	83/6
Lancashire (d/d eq. Man.)—	
Derby fdry. No. 3	74/-
Staffs fdry. No. 3	74/-
Northants fdry. No. 3	72/6
Cleveland fdry. No. 3	74/-
Dalzell, No. 3 (special)	102/6 to 105/-
Glengarnock, No. 3	82/6
Clyde, No. 3	82/6
Monkland, No. 3	82/6
Summerlee, No. 3	82/6
Eglinton, No. 3	82/6
Gartsherrie, No. 3	82/6
Shotts, No. 3	82/6

FINISHED IRON AND STEEL

Usual district deliveries for iron; delivered consumer's station for steel.

Iron—	£	s.	d.	£	s.	d.
Bars (cr.)	9	12	6 to	9	15	0
Nut and bolt iron	7	10	0 to	8	0	0
Hoops			10 10 0 and up.			
Marked bars (Staffs) f.o.t.			12 0 0			
Gas strip			10 10 0 and up.			
Bolts and nuts, ¾ in. × 4 in.			14 0 0			
Steel—						
Plates, ship, etc.	8	15	0 to	8	17	6
Boiler plts.	8	0	0 to	8	10	0
Chequer plts.				10	7	6
Angles				8	7	6
Tees				9	7	6
Joists				8	15	0
Rounds and squares, 3 in. to 5½ in.				9	7	6
Rounds under 3 in. to ⅜ in. (Untested)				8	12	0
Flats—8 in. wide and over				8	12	6
,, under 8 in. and over 5 in.				8	17	6
Rails, heavy	8	5	0 to	8	10	0
Fishplates	12	5	0 to	12	10	0
Hoops (Staffs)				9	7	0
Black sheets, 24g. (4-t. lots)				10	10	0
Galv. cor. shts. (,,)				13	0	0
Galv. flat shts. (,,)				13	10	0
Galv. fencing wire, 8g. plain				14	10	0
Billets, soft				5	10	0
Billets, hard	6	17	6 to	7	2	6
Sheet bars	5	0	0 to	5	5	0
Tin bars				5	0	0

PHOSPHOR BRONZE

	Per lb. basis.
Strip	9d.
Sheet to 10 w.g.	10d.
Wire	11½d.
Rods	10d.
Tubes	13d.
Castings	11d.

Delivery 3 cwt. free.
10% phos. cop. £30 above B.S.
15% phos. cop. £35 above B.S.
Phosphor tin (5%) £30 above price of English ingots.
C. CLIFFORD & SON, LIMITED.

NICKEL SILVER, &c.

	Per lb.
Ingots for raising	7d. to 1/1
Rolled—	
To 9 in. wide	1/1 to 1/7
To 12 in. wide	1/1½ to 1/7½
To 15 in. wide	1/1½ to 1/7½
To 18 in. wide	1/2 to 1/8
To 21 in. wide	1/2½ to 1/8½
To 25 in. wide	1/3 to 1/9
Ingots for spoons and forks	7d. to 1/3½
Ingots rolled to spoon size	10d. to 1/6½
Wire round—	
to 10g.	1/4½ to 1/11½

with extras according to gauge.
Special 5ths quality turning rods in straight lengths, 1/3½ upwards.

AMERICAN IRON AND STEEL

At Pittsburgh unless otherwise stated.

	Dols.
No. 2 foundry, Phila.	20.26
No. 2 foundry, Valley	18.50
No. 2 foundry, Birm.	14.50
Basic, Valley	18.00
Bessemer	20.76
Malleable, Valley	18.50
Grey forge, Valley	18.25
Ferro-mang. 80%, seaboard	85.00
O.-h. rails, h'y, at mill	36.37½
Billets	27.00
Sheet bars	28.00
Wire rods	38.00
	Cents.
Iron bars, Chicago	1.80
Steel bars	1.80
Tank plates	1.80
Beams, etc.	1.80
Skelp, grooved steel	1.70
Steel hoops	2.10
Sheets, black, No. 24	2.45
Sheets, galv., No. 24	3.10
Wire nails	2.60
Plain wire	2.30
Barbed wire, galv.	3.00
Tinplates, 100-lb. box	$5.25

COKE (at ovens)

Welsh foundry	25/- to 30/-
,, furnace	20/-
Durham foundry	21/- to 25/-
,, furnace	17/6
Midlands, foundry	—
,, furnace	—

TINPLATES

f.o.b. Bristol Channel ports.

I.C. cokes	20×14 per box		18/-
,,	28×20 ,,		36/-
,,	20×10 ,,		25/9
,,	18¾×14 ,,		18/9
C.W.	20×14 ,,		16/-
,,	28×20 ,,		33/6
,,	20×10 ,,		22/9
,,	18¾×14 ,,		16/3

SWEDISH CHARCOAL IRON & STEEL

	£	s.	d.	£	s.	d.
Pig-iron	£6	0	0 to	£7	0	0
Bars-hammered, basis	£16	0	0 to	£16	10	0
Bars and nail-rods, rolled, basis	£15	15	0 to	£16	0	0
Blooms	£10	0	0 to	£12	0	0
Keg steel	£30	0	0 to	£31	0	0
Faggot steel	£18	0	0 to	£23	0	0
Bars and rods dead soft, st'l	£10	0	0 to	£12	0	0

All per English ton, f.o.b. Gothenburg.
[Subject to an exchange basis of Kr. 18.16 to £1.]

DAILY FLUCTUATIONS

Standard Copper (cash)

		£	s.	d.		
July	26 ..	29	3	9	inc.	6/3
,,	27 ..	28	18	9	dec.	5/-
,,	30 ..	29	1	3	inc.	2/6
,,	31 ..	28	16	3	dec.	5/-
Aug.	1 ..	28	13	9	,,	2 6

Electrolytic Copper

		£	s.	d.		
July	26 ..	32	5	0	inc.	5 -
,,	27 ..	32	5	0	No	change
,,	30 ..	32	5	0	,,	,,
,,	31 ..	31	15	0	dec.	10/-
Aug.	1 ..	31	15	0	No	change

Standard Tin (cash)

		£	s.	d.		
July	26 ..	231	10	0	dec.	37/6
,,	27 ..	231	7	6	,,	2/6
,,	30 ..	231	5	0	,,	2/6
,,	31 ..	231	5	0	No	change
Aug.	1 ..	229	0	0	dec.	45/-

Tin (English ingots)

		£	s.	d.		
July	26 ..	231	12	6	dec.	37/6
,,	27 ..	231	12	6	No	change
,,	30 ..	231	7	6	dec.	5/-
,,	31 ..	231	7	6	No	change
Aug.	1 ..	229	5	0	dec.	42/6

Spelter (ordinary)

		£	s.	d.		
July	26 ..	13	8	9	inc.	2/6
,,	27 ..	13	8	9	No	change
,,	30 ..	13	8	9	,,	,,
,,	31 ..	13	10	0	inc.	1/3
Aug.	1 ..	13	7	6	dec.	2/6

Spelter (Electro, 99.9 per cent.)

		£	s.	d.		
July	26 ..	16	1	3	inc.	3/9
,,	27 ..	16	1	3	No	change
,,	30 ..	16	1	3	,,	,,
,,	31 ..	16	0	0	dec.	1/3
Aug.	1 ..	16	0	0	No	change

Zinc Sheets (English)

		£	s.	d.		
July	26 ..	23	5	0	No	change
,,	27 ..	23	5	0	,,	,,
,,	30 ..	23	5	0	,,	,,
,,	31 ..	23	5	0	,,	,,
Aug.	1 ..	23	5	0	,,	,,

Lead (English)

		£	s.	d.		
July	26 ..	12	15	0	inc.	5/-
,,	27 ..	12	15	0	No	change
,,	30 ..	12	15	0	,,	,,
,,	31 ..	12	15	0	,,	,,
Aug.	1 ..	12	15	0	,,	,,

AVERAGE MONTHLY PRICES OF FURNACE COKE D/D MIDDLESBROUGH

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Yearly average.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1902	0 16 9	0 15 0	0 15 6	0 15 0	0 15 0	0 15 3	0 15 3	0 15 3	0 15 6	0 16 0	0 16 6	0 16 0	0 15 5
1903	0 15 9	0 16 0	0 16 3	0 16 9	0 16 6	0 16 3	0 16 0	0 15 9	0 15 6	0 15 0	0 14 6	0 14 0	0 15 8½
1904	0 13 9	0 13 9	0 13 3	0 14 3	0 14 6	0 14 3	0 14 3	0 14 3	0 14 3	0 14 0	0 14 0	0 14 6	0 14 1½
1905	0 14 9	0 15 3	0 15 3	0 15 3	0 15 6	0 15 6	0 15 6	0 15 6	0 15 6	0 15 6	0 15 9	0 17 0	0 15 5½
1906	0 17 6	0 17 6	0 17 0	0 17 0	0 17 0	0 16 6	0 17 0	0 17 0	0 18 3	0 18 6	0 19 0	1 0 0	0 17 8½
1907	1 4 6	1 5 0	1 5 0	1 0 6	1 2 0	1 1 0	1 1 0	1 1 0	1 2 0	1 1 6	1 0 0	0 17 0	1 1 8½
1908	0 16 0	0 16 0	0 15 6	0 16 0	0 16 3	0 16 0	0 15 6	0 15 6	0 15 6	0 15 3	0 16 0	0 16 0	0 15 9½
1909	0 16 0	0 15 3	0 15 0	0 14 9	0 15 6	0 15 9	0 15 6	0 15 6	0 16 6	0 17 0	0 17 6	0 17 0	0 15 11½
1910	0 18 4½	0 18 6½	0 18 0	0 18 0	0 17 10½	0 17 0	0 16 1½	0 15 9½	0 15 11	0 16 0	0 15 9½	0 15 8	0 16 11
1911	0 16 0	0 15 10½	0 15 6	0 15 3	0 14 9	0 14 6	0 14 6	0 14 6	0 14 6	0 14 11½	0 15 0½	0 16 3½	0 15 1½
1912	0 17 3	0 17 3	0 18 6	0 18 10	0 19 0	0 19 4½	0 19 10½	1 0 9½	1 2 9	1 4 1½	1 5 8½	1 8 6	1 1 0
1913	1 5 9	1 4 11	1 5 0	1 5 0	1 4 9½	1 0 4½	0 19 5½	0 18 3	0 18 0	0 18 2½	0 18 6	0 18 6	1 1 4½
1914	0 18 2	0 17 1	0 17 0	0 17 0	0 17 4	0 17 6	0 17 6	0 18 5	0 18 4	0 17 9	0 17 6	0 18 5	0 17 8
1915	0 17 10½	0 17 9	1 0 4½	1 7 7½	1 9 4½	1 10 7½	1 9 7	1 7 3	1 5 4	1 4 9	1 9 6	1 13 0	1 6 1
1916	1 10 9	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6½
1917	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6	1 14 3	1 15 6	1 11 2½
1918	1 15 6	1 15 6	1 15 6	1 15 6	1 15 6	1 15 6	1 15 6	1 15 6	1 15 6	1 15 6	1 15 6	1 15 6	1 15 6
1919	1 15 6	1 15 6	1 15 6	1 15 6	2 1 6	2 1 6	2 3 9	2 10 6	2 10 6	2 10 6	2 10 6	2 10 6	2 3 5
1920	2 12 3	2 14 0	2 19 0	2 19 0	3 3 8	3 6 0	3 6 0	3 6 0	3 6 0	3 6 0	3 6 0	3 6 0	3 2 6
1921	3 1 0½	2 19 0	2 16 0	2 7 0	2 6 6	2 6 6	2 0 6	2 0 0	1 13 11	1 12 9	1 10 4½	* 8 3	2 3 6½
1922	1 7 0½	1 8 1½	1 9 7½	1 8 4½	1 7 11½	1 7 3	1 6 9½	1 6 10½	1 7 0½	1 10 2½	1 10 0	1 9 11½	1 8 3½
1923	1 11 3	1 14 6	2 0 1½	2 2 8½	2 4 4½	2 2 10½	2 1 0½	2 1 6	2 0 9½	1 18 9	1 18 8½	1 18 3	1 19 7½
1924	1 16 6½	1 14 9	1 11 11½	1 10 0½	1 8 1½	1 7 8½	1 7 3	1 6 3	1 6 0	1 5 0	1 5 0	1 5 0	1 9 5½
1925	1 4 10½	1 4 1½	1 13 3	1 2 4½	1 2 2½	1 1 5½	1 1 3½	1 4 9	0 18 10½	0 18 4½	0 19 6½	1 1 4½	1 2 8½
1926	1 2 1½	1 0 9	0 19 2½	0 18 6½	*	*	*	*	*	*	*	1 5 0	1 1 1‖
1927	1 5 6	1 4 9½	1 6 1½	1 3 9	1 2 6	1 0 8½	0 19 4½	0 19 0	0 18 7½	0 18 0	0 17 10½	0 17 6	1 1 1½
1928	0 17 6	0 17 10½	0 18 0½	0 17 11½	0 17 8½	0 17 6½	0 17 7½	0 17 6½	0 17 6	0 17 7½	0 17 7½	0 17 6	0 17 8
1929	0 17 7½	0 18 0	0 19 0	0 19 6½	0 18 10½	0 19 10½	1 1 3½	0 16 6	0 16 9	0 17 0	0 17 0	0 17 0	0 18 2½
1930	1 2 6½	1 1 3	1 0 3	0 19 1½	0 17 7	0 16 10½	0 16 6	0 16 6	0 16 9	0 17 0	0 17 0	0 17 0	0 16 0½
1931	0 17 0	0 16 7½	0 16 0	0 16 0	0 15 11	0 15 5	0 15 1	0 15 0	0 15 0	0 16 9	0 17 0	0 16 6	0 15 6½
1932	0 17 0	0 16 11½	0 16 5½	0 15 9	0 15 7½	0 15 6	0 15 6	0 14 9½	0 14 6½	0 14 6	0 14 6	0 15 4	0 15 6½
1933	0 16 0½	0 15 11½	0 15 6½	0 15 6	0 15 6	0 15 6	0 15 6	0 15 8½	0 16 4½	0 17 0	0 17 6	0 18 0	0 16 1½
1934	0 19 1½	1 0 6	1 0 2	1 0 0	1 0 0	1 0 0	1 0 0	—	—	—	—	—	—

* Strike period. ‖ Five months.

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